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Sincerely yours
Chas. E. Beecher

THE AMERICAN GEOLOGIST,
VOL. XXXIV. PLATE I.

THE

AMERICAN GEOLOGIST.

VOL. XXXIV. JULY, 1904. No. 1.

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CHARLES EMERSON BEECHER.

Oct. 9, 1856—Feb. 14, 1904.

PORTRAIT—PLATE I.

The sense of bereavement which follows upon a loss so disastrous to paleontology as the departure of professor Beecher renders it difficult to express lucidly and in adequate measure to those who may have known him more by repute than by personal intercourse, his real value to his science or to record an appreciative tribute to his genius. Human experience is so full of instances of brilliant abilities prematurely quenched, of fruitful lives blotted out, of promising careers terminated before the goal is reached, that the aphorisms of the world take note of them. Death loves a shining mark, indeed.

Professor Beecher's end was wholly without premonition even to the penetrating eyes that watched him most closely, and its suddenness carries an element of the tragic. The Sunday morning of his death he arose as well as ever but later he complained of pains in his arms, then in his chest. The usual household remedies failing, a physician was summoned and while they talked together he complained of dizziness and with a few breaths was gone. The hardening of the cononary arteries or *angina pectoris,* which might least have been expected in a constitution of relative youth, is regarded as the cause of death.

One often sees in midsummer an oak on which a single leaf flares out in red and yellow while all the rest are green, and here too age has stolen on with unequal pace.

Professor Beecher was in the 48th year of a singularly productive life. If his own death was an illustration of the

significance of those phenomena of growth and decline on which so much of his own best work was based, so his mental equipment strikingly exemplifies the vitality of variation. It might be difficult to locate the ancestral kernels of his peculiar mentality: the instinctive love of nature and extraordinary intentness of thought that were so pervasive of his methods and evident in his achievements.

He was born at Dunkirk, N. Y., Oct. 9, 1856, and in his youth his family moved to Warren, Pa., where his father subsequently acquired large business interests. His fondness for natural science developed early and instinctively, expressing itself in the zealous acquisitiveness of the collector. Before he entered college he had brought together an extensive series of land and fresh water mollusks, both from the home localities and through exchanges from regions more remote. He had mastered that group of obscurities, the species of the Unionidae. For long his interest in these mollusks held full sway, and he did not make formal surrender of his interest therein until in later years he found problems of broader import growing on him. Contemporaneously grew his interest in the *geology* of his home ground, but this was at no time so much a concern for its geological structure as for the acquisition of its fossils. These he collected with the greatest avidity and his zeal soon carried him afield into the well known localities of New York. After he entered Michigan University his summers were regularly spent in this pursuit. The volumes of the *Paleontology of New York*, with their profusion of illustration, were his guide and inspiration.

On a hot summer day in 1877, pale with weariness, he staggered with pack on back into the laboratory of professor James Hall at Albany. He had sought what to him had seemed the fountainhead of knowledge of his fossils. It had been the goal of many a youthful dream to show to the author of the *Paleontology of New York* the treasures he had found. The great and keen-eyed Hall ever had an appreciative reception for such endeavor. With the most friendly concern he refreshed and nursed this acolyte and when strength had returned expressed a lively interest in his efforts and his ambitions. On going away Beecher had prom-

ised to come back to Albany when his college course was done and join Hall's corps of workers on paleontology. So in the summer of 1878, the year of his graduation, he became assistant to professor Hall, entered upon his work and was received with genuine enthusiasm.

Those early years at Albany were of unalloyed happiness for the young paleontologist. His mind was not filled with dreams of fame, but he had at last reached the wellspring and could slake his thirst at will. Hall had then been for more than forty consecutive years engaged in elaborating the geology of New York; he regarded himself, as the unreserved devotee should, the personification of his work. He was the *Paleontology of New York*. He invited young blood to aid him in his work and paid in the invaluable training this work offered to his assistant, but he shared no honors. At the time of Beecher's advent in Albany professor Hall was busied with two of his tremendous monographs of the fossils embraced in four quarto volumes, and into the study of the vast group of species represented in one of these, the *Lamellibranchiata,* Mr. Beecher was gradually inducted. As a systematic work this undertaking was of giant proportions, nothing like it had been attempted in American paleontology, but, the two heavy volumes issued, it is not difficult indeed to find where the hand of the master was guided by that of the student. The plan of this, as of previous volumes, and the spirit in its execution even to details, was that of its author, but it is well to record here, as has not been done before, wherein the student forecasted, in this early work done *sub umbra,* his future fruitage. One sees through these plates instructive illustrations of critical structures, hinges, dentition, muscular scars, which were largely drawn from preparations made by the student. There is one difficult lithograph plate copied entirely from Beecher's own drawings, made because this youthful Launcelot was not content with the drawings by Hall's expert and finished artists. This is worth remarking because the standard of artistic work in the reproduction of the New York fossils was and has always been high. There was one immense group of species in this descriptive work brought together under the generic name of Leptodesma —fifty and more of them—to the everlasting confusion of all

who were called upon to use this book. Critics and reviev ers with scantily veiled disgust held this fifty up to sco as a blistering example of the sin of species making. Ar yet this was a singularly fertile and suggestive bit of wor [illegible] of Beecher's conception. The stock of the Leptode has blossomed out in late Devonic time into a profusion of e: pression. It was a rare illustration of racial vitality with vai ation and amongst thousands of specimens all possible vai ation of form, outline and proportion were present. The things appear on the pages of the book as so many allege species but Beecher had himself arrived at most of the by arranging progressive series in various lines and th seeking out their missing links. At the end of one of the: volumes are two cuts printed on the text pages. Nothing said of their mode of preparation and the user would be vei likely to pass them by as zinc cuts made from stipple drav ings. These were the product of a device conceived b Beecher for making a drawing on ground glass with lith graphic crayon, as a subject for photoengraving. But thoug he devised and perfected the process independently it wa not employed as the inventor had the melancholy experien of finding his process already copyrighted.

I have referred to these various matters for here in a pr tentious work in which the young paleontologist took his fir part we find such decided evidence of the quality of h biologic concepts, his preparative skill, his artistic facility an his mechanical ingenuity and dexterity.

Professor Hall had a fearless way of committing his Stat to his scientific projects. He would begin several elaborat and very different monographs at once, having drawing an lithography done for each until he involved a provision fro the State necessary for the completion of all. A single volum would be years on the way, and so it happened that in Beecl er's early years at Albany a memoir on the Devonian cepl alopods, gastropods and pteropods appeared almost simulta neously with the other and though this was more nearl completed at the time of his coming, there were many ev dences of nice final touches on the *Cephalopoda* which cam from him. With the exception of a few supplementary descrip tions of cephalopod species published in a later volume of th

Paleontology, Beecher's appearance in those volumes here ended. He had done no little to refine and advance the work, but his reward was his experience and with this he seemed fully content.

During this period however he was busied with various other things. He had not wholly lost his keen interest in the terrestrial mollusca and he kept in close touch with students and collectors in the east, adding considerably to an already very extensive collection of these shells which eventually he gave to the State Museum. He had made himself expert in microscopic technic and some of his fine mountings of the radulas of gastropods were the subject of contributions to conchological papers. He undertook the microphotography of fossils with success, and he became much interested in human histology and anatomy.

In these days and always Beecher was a keen collector of fossils. He had not the physical strength for the omnivorous and ponderous effort of that kind but he was the most discriminating acquirer of the unusual, the exceptional and the fine, that it has been my fortune to know. In those days at the Albany museum the private collection was permitted, it was indeed to the assistant an outlet for individual endeavor and a basis for extra-official labor and research. He held with the rest of us firmly to the belief that a student of natural science without a private collection or at least the impulse to it was in danger of becoming either a starveling or a machine. As a student of paleontology, however, new species were interesting him less and less; it was something new about old species that he sought and these new facts were acquired by various avenues and new devices.

In looking over the list of his early papers one sees how gradually he was finding himself. Of the 13 publications issued before he left Albany for New Haven the majority were conchological, only four can be regarded as paleontological, yet this may be somewhat due to the very evident sense of repression he felt along the line of the latter.

A part of Mr Beecher's fine natural equipment for scientific research was his indomitable patience necessary to establish broad premises. His conclusions were never hasty nor ever stated on merely one aspect of the evidence. All the more

far-reaching and striking of his deductions in his later work when his mind had turned chiefly to problems of biogenesis are known to his friends to be the result of tireless acquisition of material and the focussing of light from every source. In some quarters, his methods unknown, their results were not accepted; they were regarded as startling, as iconoclastic and even unreliable.

It is well that here a word be said in detail as to what his preparation was before a publication appeared. In our mutual association in Albany we undertook a study of the ontogeny of certain brachiopods from the Upper Siluric at Waldron. The materials for this study were the fine washings from some tons of specimens brought to Albany by the museum's collectors. Herein lay every stage of development of these shells. Night after night for a whole winter we sorted out this material until we estimated that fifty thousand immature brachiopods had been selected and arranged in ontogenic series. His studies of the larval and development phases of the brachiopods and trilobites were chiefly based on etchings from the limestones of the Helderberg and Canandaigua lake. These too were numbered, by thousands. When he published the anatomy of the trilobite Triarthrus, an English author wrote me "confidentially" to know if it was to be trusted. A continental paleontologist with a single sandstone cast of a trilobite's ventral surface, destructively attacked his work, intimating that it was a dream, a castle in Spain. He did not know that Beecher had a thousand specimens back of him to prove his work and a hundred preparations which for delicacy and exactitude have had no equal.

In 1888 Mr Beecher was invited by professor Marsh to go to New Haven in the capacity of assistant in the Peabody Museum in charge of the invertebrate fossils. Matters in Albany were not just at that time in form to present a counter attraction. Professor Hall was undergoing one of the periodical "investigations" with which he was frequently favored. Sometimes these were instigated by unsympathetic interests in the state legislature, but at this time by a personal hostility at the head of the Regents of the University. Whatever their source, [illegible] one issue to these inquiries and that the [illegible] of the man and his work.

At the time Mr. Beecher was leaving Albany he was appointed by the interests hostile to Hall to a newly created position on the Museum staff, "consulting paleontologist," but this was so direct an affront to Hall that with the termination of the inquisition, the place was at once discontinued.

Mr. Beecher's life at New Haven opened under the happiest auspices in a new and clearer atmosphere freshened by inspiring associations and in his future work he won and kept the confidence and loyal support of his colleagues and patron. Soon after his coming, and as early as his museum duties allowed, he began his series of biogenetic studies which have been of wide-spread influence on his science and have established the high repute of his work. Among two groups of organisms he found the subject matter of most of his future studies, the brachiopods and the trilobites. His investigations on the former, constituting the earlier series, were inspired by the studies under way at Albany in preparation of the elaborate two volumes on these structures. He kept in close touch with those investigations through his intimate acquaintance with Mr. Schuchert and the writer, and most profitably followed out some of the suggestive points therefrom developed. His important series of papers on the trilobites may be regarded as originating in the impulse given by Matthews's announcement of antennæ in Triarthrus becki from the Utica shale at Rome, N. Y. Aided by a lease of the locality of these interesting fossils taken by professor Marsh he was enabled to acquire almost unlimited material and his preparations of the pyritized appendages of these creatures are as fine exemplifications of his skill in this kind of handiwork as his exposition and reconstruction of the anatomy of the animal are of the accuracy of his correlative powers. With this series of papers is to be associated his determination of larval and later morphology in other trilobites, all resulting in his classification which has altogether revolutionized previously accepted schemes.

In all his work of research, whether at Albany or New Haven, he evinced only a rather remote and occasional interest in problems of geology or stratigraphy, rarely even in stratigraphic paleontology. In the maturer phases of his thought he was concerned so wholly with the problems of phylogeny

and biogenesis that the questions of time relations among organisms, of range, distribution, paleography, were largely excluded. This is so singular as to be notable, for Beecher was essentially without academic training in biologic science; he was, however, trained and experienced in stratigraphic paleontology, or at least in its requirements. Wherein he had no interest he had little sympathy though he did not lack in appreciation. He was a forcible illustration of the fact, and to it he himself would occasionally refer, that for excellence of achievement in the strictly biologic problems of paleontology a geological training is a more essential equipment than a biologic one, for with the latter only the student never becomes thoroughly at home amongst the fossils or ever ceases to bemoan the loss of the soft parts; never fully apprehending a fossil as a joint product of biologic and geologic agencies. The [illegible] of this expression is certified to on every hand in the [illegible] of the science he loved best and cultivated most.

[illegible] satisfactory reflection that a mentality of un[illegible] can be so brought under the in[illegible] to become as much the creature of cir[illegible] powers. I can not see where[illegible] from his intercourse with either [illegible] paleontologists Hall or Marsh, that [illegible] intellectual powers, but on the [illegible] was given to him by his [illegible] Alpheus Hyatt. This [illegible] delightful personality [illegible] that one might [illegible] Hyattian meth[illegible] The applica[illegible] of growth [illegible] of the [illegible] Of [illegible] no[illegible] fitably [illegible] would [illegible] re[illegible] nesis [illegible] tional [illegible] such

schemes to be of this type in which the sum of all anatomical characters rather than variations in one lie at the base; the two just referred to and Hyatt's classification of the cephalopods. Beecher's schemes are less obscured with detail and analysis of phylogenetic status and hence more adaptive to practical application. Hyatt evinces at every stage the analytical grasp of the growth phase and its rapid utilization in classification resulting in a much more complicated and detailed, if less readily applicable scheme. The latter in creating an army of new taxonomic values and names has at the same time created the necessity for as many more for phases of like value still unexpressed; the former has built without such close analysis and his terms suffice. Hyatt's classification it seems to us will stand less well the test of time than those of his disciple, but Hyatt's powers of analysis and correlation in this line of biogeny are still unparalleled. Out of Beecher's study of the ontogeny of fossil brachiopods and trilobites came his noteworthy treatise on the Origin and Significance of Spines, in which the fact, recognized though not emphasized before, that the development of spines is an indication of the decline in racial vitality which precedes extinction, is set forth with a wealth of demonstration.

The papers we have mentioned will be regarded as the broadest in scope of professor Beecher's undertakings, but they are not of more permanent value than many of his less pretentious publications.

As a teacher of his science Dr. Beecher had won an enviable success. His courses were attended with zeal and interest and among his graduate students are some whose work in his own department of the science has reflected much credit on him and on themselves. He had also received substantial recognition of his achievements in the honors which had come to him. The position he occupied in Yale as University Professor of Paleontology, Professor of Historical Geology in the Sheffield Scientific School and Curator of the geological collections in the Peabody Museum was his most signal distinction. He was also a member of the National Academy of Sciences, Foreign Correspondent of the Geological Society of London, etc. For two years he was President of the Connecticut Academy of Sciences. The record of his published works as given in the following list discloses but a part of his

actual achievements, the greater part being the esteem and loyal devotion of his associates and students.

JOHN M. CLARKE.

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Member of the National Academy of Sciences; American Association of Conchologists; Connecticut Academy of Arts and Sciences; Geological Society of Washington; Malacological Society of London; Boston Society of Natural History; Fellow of the Geological Society of America, Foreign Correspondent of the Geological Society of London.

(Prepared by Lucy P. Bush, Peabody Museum.)

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THE SEDIMENTS OF THE MEGUMA SERIES OF NOVA SCOTIA.*

By J. Edmund Woodman, Halifax, N. S.

CONTENTS.

*The second of a series of papers, having a common origin, on the Meguma series of Nova Scotia. The first appeared in this journal, vol. xxxiii, pp 364-370.

In a first paper the limits of the gold-bearing metamorphic series of Nova Scotia were sketched roughly, and a nomenclature proposed for the series and its two subdivisions. In the present paper and those following, these formation names will be used without further explanation. The metamorphism of the sediments will be treated in a later paper.

The Goldenville formation.

Definition. The division of the Meguma series into two formations depends upon a sudden change from strata prevailingly gray and dark green in color in typical regions, and largely siliceous in composition and arenaceous in texture, to superjacent conformable beds which are for the most part lead colored or black, in some places light gray and light green; and almost wholly argillaceous in character. The change is so abrupt as to be readily recognizable, whether the base of the Halifax formation be black or green.

Distribution. The Goldenville formation furnishes the ground upon which the upper member is laid in east-west synclinal bands, in surface distribution. This results from its position below the other and its greater thickness, from the sharpness and persistence of the folds throughout the series, and from the superior resistance of its rocks to erosion. Only a few localities are known in which it forms isolated patches surrounded by Halifax slates. In the east the most interesting is the Caribou mining district, which is located at the summit

of the Goldenville formation. The usual syncline of the Halifax has been puckered into two, with an anticline between; and this has been domed up at Caribou, and eroded far enough to show the summit of the Goldenville strata beneath. In the west, elliptical areas of this group, on the "banded argillyte" as a background, are mapped as occurring in several instances, up to a score and more miles in length (Bailey, '98, map).

Contact with the Halifax formation.—The contact between the two divisions of the series is always sharp where actually observable. It is usually marked by a striking change in color of the strata, from the greenish and grayish of the lower rocks to the black, or less often light green, of the upper. Faribault ('87, pp. 146-147) speaks of the contact as characterized by "a few layers of greenish, soft, smooth slate;" but these are absent in many regions. They are the eastern equivalents of the "banded argillyte" of Bailey. Nowhere has the slightest unconformity been seen between the two; one being a continuation of the other as regards process of sedimentation, and differing from it only in color, texture, and kind of material.

Base unknown.—The problem of the base of the series is insoluble at present. It is easy to find the lowest rocks, fundamental to our observation; but there is no information which gives any clue as to the depth of unknown Meguma below the surface of the earth, in the center of the Moose River—Fifteen Mile Stream anticline, which holds the lowest known strata in eastern Nova Scotia.

Thickness.—This makes impossible of answer the question as to the real thickness of the formation. The exposed thickness of the series and its subdivisions has been computed by several students of the field. Hind ('70, '70[a], '70[b]) first estimated the thickness of the whole series, calling it 12,000 feet. The opposite extreme is Prest's estimate of 28,000 feet (Bailey, '98, p. 83). Hind (loc. cit.) gave 9,000 feet as the thickness of the lower formation. Faribault ('87) gave 15,000 feet at first, and later ('99, p. 2) regarded three miles as the depth to which erosion had exposed these beds. Bailey ('98, p. 31) gives 5,000 feet as a minimum, indicating thus the greater difficulty of exact structural work in the west.

The two best localities for measurement, in eastern Nova Scotia, are from the Moose River anticline, at its bifurcation a mile west of Moose River mines, north to the contact with the Halifax formation; and from the more northerly of the two branches into which that axis breaks, five miles west of Fifteen Mile Stream gold district, north to the contact with the Halifax. The former gives 16,730 feet, the latter 17,670 feet as the exposed thickness of the Goldenville. Strike faults are extremely rare in the Meguma series, and small where found. The traverses made for the purpose of estimating thickness were along lines giving numerous outcrops; and no evidence whatever was found, which would warrant belief in either folding or faulting along the lines measured.

Characteristics of sediments: psammytes.—A few conglomerates are to be found in this formation, but are most conveniently described later. Finer than these is the "whin," including sediments of all textures between conglomerates on one hand and slate on the other. These strata exhibit all degrees of compactness and metamorphism, from somewhat friable sandstone to the most dense and highly metamorphosed quartzyte; the latter being abundant and the former rare. As a rule they are heavily bedded, single strata reaching thirty to forty feet in thickness in some instances, without sign of stratification. On the other hand, some are but a fraction of an inch thick. The color is generally dark green when fresh, becoming brown through oxidation of sulphides, and finally bleaching by continued weathering to a yellowish or light greenish gray. Under a hand lens, one of the most noticeable features is the abundance of grains of black or dark smoky quartz in some of the coarser whins.

The texture of these whins ranges from coarse grits, almost conglomerates, to fine quartzytes with some admixture of kaolin. Of the former, the thick whin belt at Mt. Uniacke is a good example. Very considerable masses of quartzyte are so uniform as almost to prevent structural relations from being deciphered. Frequently a zone of more noticeably cleaved rock or an indistinct lamina of slate is all that can be relied upon. The lack of individuality in the arenaceous sediments is so marked that there is no opportunity for finding

datum planes which can be used as a basis for the larger structural problems. It may be that, on the whole, the whin is more abundant and somewhat coarser near the base of the formation, becoming finer above; but the differences are neither strong nor persistent. At certain horizons, in restricted districts, the whin forms a noticeably small proportion.

Characteristics of sediments: slates.—The slates vary less than the whin. Their color is usually a bluish or greenish black, often altered by chlorite to a somewhat lighter green, or by the rusting of sulphides to a brown. Their commonest surface color when well weathered is gray. Color changes are by no means so frequent or so violent as in the green slate section at the base of the Halifax formation. In thickness the slate is often a mere parting in the quartzyte, and seldom attains a greater amount than a few feet in a single stratum. Usually it is a few inches or less. The rock is in places graphitic, but not commonly or so noticeably as in the overlying formation. Near the base of the series slate is said to be less abundant, and the belts thinner on the average; yet at Moose River, whose rocks lie almost at the lowest known level in the formation, there is a belt of slate of considerable thickness, with a very small amount of whin within it. The highest proportion of slate to whin is stated to be found near the center of the Goldenville, but of this we have as yet no proof. In most of the gold districts this rock is distributed in thin belts between well-defined quartzyte walls; and this has determined in large part the position and character of the mining districts. Oldham, Goldenville, and Montague are good examples.

Proportion of slate to quartzyte.—By far the larger part of the Goldenville formation is composed of sandstones, quartzytes, and their more metamorphosed schistose equivalents. At what may conveniently be called the "horizons of most abundant slate," exposed on the domes now worked for gold, it yet, by measurements in a number of districts, averages less than 20% of the whole. In parts of Moose River it amounts to much more, but the district is exceptional. In the westernmost quarry, areas 70 and 71 block 1, the rock is 33% slate; in one of the cross-cut trenches 60%, and in several other parts of the district nearly 50%. Estimates based upon the thickness of these slate horizons on the different anticlines,

and their number, indicate that the workable parts of the [illegible] occupy but a small proportion of the thick-ness of the Gold [illegible] It is probable that the slate comprises [illegible] total thickness exposed in the formation.

[illegible] slight error arises in neglecting the slate beds and [illegible] lie in the thick whin belts between the an-ticlines [illegible] indicate that this would not increase the [illegible] than 5%. Another source of uncertainty [illegible] of the strata. Between Moose River and the [illegible] Halifax formation on the north, there is [illegible] 1% of slate, in a thickness of over 16,000 [illegible] similar sections at some other place, on [illegible] be found several times that amount.

[illegible] *distribution of slate horizons.*—Moreover, these [illegible] erratic distribution in vertical suc-cession [illegible] rhythmic alternation of whin and slate. [illegible] great depths of quartzyte almost barren of [illegible] which have a considerable proportion [illegible] the thickness of these whin belts varies [illegible] ranging from somewhat less than a [illegible] and feet. It is impossible to give [illegible] between the slate bearing horizons, be-[illegible] no probability that these ho-rizons [illegible] lateral extent to run under and over one [illegible] that would give a vertical arrangement in [illegible]

[illegible] *of strata on the dip.* The question of the [illegible] individual strata or groups of strata is a puzzling [illegible] absence of any distinctive horizons within the [illegible] formation contact plane, makes exact state-[illegible] But the slate horizons exposed by denuda-[illegible] offer a partial substitute. At about the [illegible] Moose River there are five anticlines, from the [illegible] south to the Carboniferous lowland on the north, [illegible] the Moose River and Caribou folds. These are, from north to south, the Gold Lake-Goldenville, Moose-land Gegogan, Lake Catcha Salmon River, Tangier-Harrigan Cove, and Southern anticlines ([illegible] Geol. Surv. Can., docs. 611, 624, 634; N. S. sheets 49, 50, 51). Within a few min-utes of longitude east and west the mining districts of Gold

Lake, Mooseland, and Tangier are situated on three of the arches. A cross section of the region shows that none of these anticlines give horizons at the surface which are exact stratigraphic equivalents of each other. From the axis at Moose River at the lowest known horizon, to the upper contact of the Goldenville formation on the north, the dips are all north; and give about 16,900 feet of strata. Allowing 400 feet as the maximum thickness of the slate horizon at Moose River, there are 16,500 feet of Goldenville strata stratigraphically over it; and in that thickness at least three zones of slate-bearing rocks should appear.

Three good traverses are possible from the Moose River axis northward in and near the district of that name—a western one, two or three miles west of the main settlement, along the old Moose River road north to Higgins settlement; a second along the present road north from Moose River mines; and an eastern one, three miles east of the mines, along the disused road through the Icelandic settlement. All these traverses give numerous exposures, and it seems impossible that slate-bearing horizons aggregating probably 4500 feet in thickness, should escape observation; but they have not been seen. Moreover, the vein-bearing horizon at Caribou shows no slate or leads where it emerges again from under the Halifax formation, south of Caribou. These facts would indicate that not only do individual strata extend a comparatively short distance north and south, but that whole groups of strata, representing individual and localized conditions of deposition, are quite circumscribed in their extent. Indeed, it is often impossible to match strata satisfactorily on the opposite sides of a single anticline and within a few hundred feet; and this, too, with good artificial exposures.

Continuity of strata: along the strike.—The same criteria are more difficult of application directly along the strike, because the pitch of the domes is always gentle compared with the dip of the legs of the anticlines. One case, however, is especially noticeable. The dome at Caribou, Halifax county, is located at the top of the Goldenville formation; and its position is closely defined by the only exact datum plane we know—the contact with the base of the Halifax. Eastward ten miles, along the same axis, the Goldenville emerges from

the cloak of black strata; but no horizon of vein-bearing slates is known. Moreover, very many points of contact between the two formations have been seen by various observers, but I cannot find that any horizon similar to the one at Caribou has been noted. The fact that there is no striking similarity in succession of strata between the various domes on the same anticline, especially where, as is true in several instances, more than two domes have been made on the same axis, also points strongly to the same conclusion reached in north and south traverses. The strata of this formation are markedly discontinuous in all directions; and this is especially true of its finest sediments, which in other countries are normally persistent to a greater extent than coarse ones.

Conditions of deposition.—The few and local conglomerates of the Goldenville have in no instance been proved to lie at the base of the series; hence we cannot learn under what conditions its deposition began. We know, however, that these were so unstable as to cause the accumulation of fine and coarse material alternately through the period of action, the latter strongly predominating. The conglomerates indicate a probable shore line not far distant at some time or times. The sands and grits show a condition of quite shallow water during most of the sedimentation; but the slate horizons do not, on the other hand, prove an oscillation of the sea bottom. Such changes of level are more or less widespread, and the slate strata in the formation appear not to have a lateral extent commensurate with that condition. Moreover, many slate partings are too thin for their deposition to have occupied the whole time required under normal conditions of sedimentation, while such a secular change of depth was in progress. They are, however, readily explained by more local and transient causes.

The sudden and blunt ending of strata in some cases, as at West Waverly; the rapid thinning of others, as the whin overlying the Jo. Taylor belt of "leads" at Moose River mines; the very apparent non-persistence of individual and grouped strata over extensive areas, so that the beds are much more found in most other formations of great area and frequently no coarser,—all appear to me best explained in one way, not commonly employed in accounting for the presence of extensive

series of strata. This is by the deposition of the sediments of the Goldenville in moderately shallow water, upon a floor essentially flat under the area now covered by the strata, and influenced by somewhat violent currents and waves, constantly shifting their relations. Tidal changes in depth of water and direction of transportation may suffice to account for some of the phenomena of distribution of sediments, but not for all. These currents created unevennesses of bottom through differential deposition, and changed the character of the detritus in any place suddenly, according to the direction and force of the flow at the time.

The known thickness of the formation is more than 17,000 feet. How much lies below the exposed part we cannot tell. It may be considerable; it can hardly be less than hundreds of feet, and probably amounts to thousands. The top is not essentially different from the bottom in texture. There is perhaps a finer average of the whin and a greater abundance of the slate near the center, although any difference which exists is not marked. Taken as a whole, the quartzytes keep their texture, and there is no such progression from a coarse base to a fine summit, or vice versa, as often is found. This indicates that the conditions of sedimentation were the same at the top as at the bottom. But the 17,000 feet represent solid, compact rock. How much bulk the sediments lose by superincumbent pressure and by loss of water, both during and after deposition, it is difficult to estimate. It is safe to say, however, that the strata now exposed would, in their original uncompacted state, have occupied a vertical column far higher than the present thickness of the formation. This does not mean that they were ever thicker to that extent; but it does mean that, to keep the sea bottom at a fairly even depth, the sinking of the original bottom, minus the compressive compacting of the lower strata by those continually forming over them, must have been equal to about 17,000 feet, and possibly more. The theory of the deposition of these sediments under the influence of currents lends itself readily to this view of the position of the sea bottom and the sinking of the detritus.

The Halifax formation.

Distribution.—The Halifax formation is distributed in narrow zones or bands, running with the general strike of the

series, and appearing to be inlaid upon a background of the Goldenville. In the field, and on such geologic sheets as have been published for the eastern half of the province, it is noticeable that these bands taper at both ends, with a resulting canoe-shaped outline. The intervals between the zones vary greatly, as do their widths. Thus, between the nearer margins of Halifax strata in the Waternish and St. Mary's Bay synclines, in the longitude of Indian harbor, there is an interval of eight miles, occupied entirely by strata of the lower formation. Between the Waternish and Sherbrooke synclines the Goldenville beds cover six and one-half miles across the strike. On the other hand, between the Ruth Fall and Liscomb Harbor synclines, they are in one place only half a mile wide. This is, however, exceptional.

It is difficult to estimate the relative areas occupied by the two formations. Conditions in the western half of the province are very different in this, as in other matters relating to the distribution of the two groups of rocks. An average of five traverses at different places east of Halifax, and aggregating over fifty miles, gives a distribution in the ratio of about one of Halifax to five of Goldenville strata, across the strike.

Character of sediments.—The rocks are chiefly slates, often very fine grained and evenly bedded. Indeed, in many places it is necessary, in the study of structure, to take advantage of the fact that crystals of pyrite lie abundantly in the stratification planes. The color of the slates varies from dull black through shades of blackish gray to light gray, and light olive green. There is rarely, if ever, the peculiar dark green given to some of the slates in the Goldenville by an abundance of chlorite and more indefinite hydrous silicates. In few instances would a hand [illegible] each formation, placed side by side, prove confusing.

The black slates are [illegible] litic, and to an extent indicating [illegible] waters in which the Meguma [illegible] they also contain such [illegible] generally along the stratification [illegible] a characteristic rusty [illegible]

Such [illegible] unimportant in quantity, and [illegible] horizons as to

be of use stratigraphically is not known. They are never, so far as I have observed, of as coarse texture as some in the Goldenville, which become grits; but their color is in cases identical, and often only their association with earthy black or green slates distinguishes these quartzytes from similar beds in the lower formation. Hand specimens are insufficient.

Continuity of strata.—It is impossible, because of the absence of structural domes developed for mining purposes, to say whether the strata are widely continuous or not; but one fact is important in this connection. While in the Goldenville it is common to find blunt terminations to thin strata, emphasizing their lens-like shape, such phenomena do not appear in the Halifax, to my knowledge. The finer texture of the sediments of the upper formation also argues for a probable greater equality of the conditions of deposition, hence more extended laminae and strata.

"Banded argillyte division."—Very rarely within the formation, but abundantly near its base, occur strata of light material—"greenish, argillaceous and chloritic soft slate," of little thickness at the east end of the province, but increasing to a considerable thickness at the west end. A few layers of magnesian siliceous limestone have also been noted at different places, at the base of the group, overlying conformably the quartzyte of the lower division (Faribault, '99, p. 2). In the west, Bailey ('98, p. 28) mentions gray, green, and purple slates, most of the green, purple and blue being grayish; often alternate in color, and thin bedded. Some quartzyte strata are interspersed.

It is this which Bailey has called the "banded argillyte division" (loc. cit.). He states, however, that there is a gradual transition between the quartzyte and banded argillyte, and between the latter and the black slate. In the east of the province these beds are never more than a few feet thick, and are often absent altogether. In the west they are said to attain a thickness of several thousand feet. In the former region, no one who has studied them has given evidence of a belief that they should be erected into a separate formation. In the field they appear merely as a basal phase of the Halifax. Traverses of a number of the areas in the western country have made me doubt the necessity of such a division there, much of the meta-

morphic material placed under it being readily referable to one or the other of the two great divisions. Indeed, the mapping of the region on a three-fold basis brings out some incongruities; as in the eastern part of the field mapped by Bailey ('98, map), where a large patch of the Goldenville is shown adjacent to Halifax strata, with none of the "banded argillyte division" between.

On the whole, therefore, it seems best not to name a third formation until stronger proof has been presented of its importance as a separate stratigraphic part of the Meguma series.

Erosion from top of series.—The original summit of the series has been lost through erosion, or at least has never been found in the most favorable places—the centers of synclines. Thus we have no knowledge of the thickness of the undenuded Halifax formation. Moreover, we have no adequate criterion by which to judge how much of it has been lost. The small amount of territory covered by it at present, scarcely five per cent, of the area of the series, indicates that a large proportion of its original hight must have gone.

At the west end of Tor bay, near the eastern extremity of the province, there are two very strong synclines of adalusite schist. Faribault ('87, p. 149) regards these as perhaps a superjacent series. But they appear to be better regarded as a more highly metamorphosed part of the Meguma; for if they are a newer series conformable with the lower, the Halifax formation which immediately underlies it is, complete, only 1800 feet thick. The mining settlement of Rawdon is situated on reddish slates which are thought by some to be a formation overlying the Halifax conformably; but as to that there is no conclusive evidence as yet.

Thickness.—Estimates of thickness vary greatly. Hind (70, 70[a], 70[b]) called it 3,000 feet. Bailey ('98, p. 46) gives 3,000 feet as a probable minimum for the black slates. But this estimate does not include the "banded argillyte division," at least a part of which probably can be regarded for the present as within the Halifax. If it really represents a westward thickening of the thin bands of the east, it is fair tentatively to include all of it within that formation. No statement is made, in the paper referred to, as to the thickness of these banded

argillytes. Faribault ('99, p. 2) calls the Halifax roughly two miles in thickness.

The thickest sections of which I have direct estimate are (1) in Halifax county on the Caribou anticline, two miles west of Caribou settlement at the end of a dome of Goldenville rocks which projects through the Halifax, the latter appearing to be 4,600 feet thick; (2) in Guysborough county on the St. Mary's Bay syncline, a mile west of where West river crosses it, the formation measuring here approximately 4,800 feet; and (3) Halifax peninsula. This last is the only instance, at least in the eastern part of the province, in which the Halifax attains a considerable breadth by repeated folds; and here, unless unknown strike faults are present, the thickness is approximately 11,600 feet. Strike faults are rare throughout the series, and the few known are extremely small and local. There is, moreover, no proof of such faults of any appreciable throw, in the many exposures in the city of Halifax.

Conditions of deposition.—The conditions of sedimentation in the Halifax were much more uniform than in the lower formation. The scarcity of quartzytes and the fineness and evenness of texture of the slates, indicate somewhat deeper water with little of the action which gave to the Goldenville its peculiar distribution of strata. The normal conditions of deposition prevailed. The deeper water signifies either a more distant land mass, or one worn much lower, so that not much material coarser than mud reached the off-shore bottom. A few limestones are reported from various localities; and especially are thin layers found at the base of the formation. One, of a black color, outcrops on the east side of Halifax harbor. Wherever found, these indicate a nearly complete cessation of mechanical deposition. But usually the change from the lower to the higher group of rocks is marked by the light green, gray, and black banded slates. These apparently indicate a slightly different source of material; and their greater thickness in the west than in the east suggest one or more of three conditions: either a larger body of rock in the western part of the pre-Meguma land mass, from which this could come; or a quicker subsidence in the east than in the west; or the presence of the pre-Meguma land nearer to the western seat of deposition. I know of no way to decide between these

possibilities. They are not, indeed, alternatives, as any two or all three may have obtained. From other evidence, it seems probable that the last of the three, at least, existed.

Evidences as to the depth of water during deposition.

Texture of sediments.—The varying texture of the sediments affords an index of slight probable differences in depth of water in some cases. For instance, Hind ('72, p. 76) mentions near Coxcomb lake, Mt. Uniacke, a belt of sandstone 380 feet thick, a grit at the bottom, becoming steadily finer upward. Many of the coarse sand grains are a translucent blue color. This, it may be remarked, is characteristic of much of the coarser quartzyte of the series, the grains being often black, or a dark smoky brown.

Limestones. A limestone has already been mentioned. Hind ('72, p. 78) writes of "twisted and contorted slates with bands of carbonate of lime" at Mt. Uniacke; but these bands were probably the stratified veins. The Goldenville formation contains much lime as a cement in the rock; which may have come originally from organisms or have been introduced by vapors and surcharged waters working interstitially, or have been an original constituent of the feldspathic components of the sands. In view of the arkose nature of much of the quartzyte in different parts of the formation, and the amount of kaolin present as shown in thin sections, the last supposition appears reasonable. Any sedimentary lime, however, is evidence of a lack of clastic material in the water, and either of such deepening of the water as ceased to allow mechanical detritus to be carried so far, or a change in current action whereby no sediment was fed to a part of the bottom, and the calcareous and siliceous ooze gathered for a period unmixed with mud.

Cross-bedding.—Cross-bedding has not been mentioned by any author as characteristic of any of the horizons in the series. It is found in a number of localities, widely separated geographically and stratigraphically. Beside the shore road of the west coast of the province one and one-half miles south of the village of [illegible] Harbor, is an exposure giving a structure which shows deposition from the south. The dark biotite schist is similar to [illegible] of the region. Near the same stratigraphic horizon [illegible], another evidence of shoal water. [illegible] Halifax harbor con-

tains many feet of finely cross-bedded quartzytes, giving conflicting evidence as to direction of current.

Ripple marks.—These are mentioned occasionally in the literature of the series. Hind ('72, p. 78) speaking of a detailed section made at Mt. Uniacke in 1869 by A. Michel of the Geological Survey of Canada, alludes to a "slaty sandstone—ripple-marked dip 71 north." Bailey ('98, p. 56) speaks of the rocks of Lockport island, Shelburne county, as distinctly ripple-marked. Certain strata on the west side of Halifax harbor show the same phenomenon.

Conglomerates.—Conglomerates have been reported from a number of localities, chiefly in the western half of the series, and all in the lower formation. The eastern occurrences noted in literature are at Mt. Uniacke and West Waverley. At the former place Hind notes ('72, p. 78), in the cross-trenched section by A. Michel, a stratum of "slaty sandstone holding a few slate pebbles." In the latter district, the same author mentions ('69, p. 21) in the Tudor group of beds, "heavy-bedded gray whin, holding pebbles of blue-black slate." In the strata accompanying the Rose group of leads, he speaks of a "fine-grained whin, holding a few pebbles of the dark bluish-gray slate." In a careful survey of the district I did not find any true fragmental pebbles, either in the strata mentioned or in others. What I have found, however, is a number of lenses of slate in the quartzyte, some but a few inches in length; and the blunt ends of others. All are flat, their shape ranging from that of rather flat ovoidal concretions to thickened discs. That they are not concretions is shown by their composition, and the disposition of the material. There are, however, certain horizons of concretionary quartzyte at West Waverley. There are a number of localities containing concretions which might be taken for pebbles at first sight by some; as, for instance, Moose River mines and the west side of Halifax harbor, near York Redoubt.

In the west, Bailey reports conglomerates from a number of localities. Near Port la Tour, Shelburne county ('98, p. 59), is a true conglomerate, "mainly of quartzyte" (MS letter). At the settlement of Pubnico Harbor, Yarmouth county, he speaks of "the inclosure in the beds of numerous well-de-

fined pebbles, mostly a quartzyte, the rock being really a "quartzyte" ('98, pp. 67-68).

A mile south of the village of Pubnico Harbor, where the railroad to Barrington crosses the same road mentioned in connection with cross-bedding, is a sericite schist, altered from a sandstone, and containing olive-green quartzyte pebbles, somewhat resembling massive serpentine. This is probably part of the formation noted by Bailey in the same region. The schist has much fine biotite irregularly distributed through it. The pebbles are sufficiently resistant to stand out well on the weathered surfaces, and occasionally these surfaces show pits [illegible] of the pebbles.

[illegible] Western Head, south of Lockport, Shelburne county, [illegible] include some . . . beds made up of well rounded [illegible] pebbles of the size of bullets" (loc. cit., p. 56). In [illegible] strongly conglomeratic rocks of Yarmouth, he [illegible] pebbles up to a foot in diameter, of gray [illegible] strata, in others of a "gray or purple-gray [illegible] which he has not determined. In a MS. letter [illegible] feldspathic, and recalling the vesicular [illegible] of Huronian age underlying the Cambrian [illegible] John." He considers them practically [illegible] his classification; but on the map [illegible] the whole region is colored as division [illegible] division."

[illegible] county, near the mouth of a brook [illegible] is said by Bailey to be [illegible] conglomerate, the cement of [illegible] p. 58). A traverse of the [illegible] to discover the strata, nor [illegible] pebbles [illegible] The nearest [illegible] small piece of [illegible] matrix being [illegible] hundred yards [illegible] by Bailey in [illegible] is a vein [illegible] been faulted [illegible] into a [illegible] conglomerate.

Origin.

Pre-Meguma continent unknown.—The Meguma series stands almost alone among the large stratified groups on the continent, in having no rocks visibly subjacent to it, in vertical or areal distribution. Neither bottom nor margin is known. The granites show no horses of a foreign and presumably older series. The conglomerates give little hint of what must have been a very large land mass. The schists of the Yarmouth region were at one time regarded as subjacent to the Meguma series, but are not now so considered. In the east, Faribault says ('87, p. 146) "The base of the quartzyte group is characterized by the occurrence of coarse quartzyte and grit in certain beds which, at the mouth of St. Mary's river, appear to be underlain by bluish-black and greenish siliceous slate holding small crystals of andalusite or staurolite." But no proof of the separateness of these rocks is given, and they may well be only a more highly metamorphosed part of the Goldenville formation. Nor does the author show, either in the text or the map sheet (nos. 28, 29; Geol. Surv. Can., docs. 382, 383), that they lie at the base of the series.

The southern, western, and part of the eastern margins lie under the sea, the original shore regions having of course long since vanished. The northern and part of the eastern margins lie under younger sediments.

Problem of original dimensions: original extent and thickness.—Evidence as to the original dimensions of the series is circumstantial only, like that for several other factors in its history. Its lateral extent must have been much greater than at present. The only hint of the proximity of the pre-Meguma land comes from the few conglomerates, chiefly in the west. None of these have been proved to be basal, hence cannot be used as arguments for the proximity of the shore at the beginning of sedimentation. At the east, the present strike of the series carries its northern contact clear of the south shore of Cape Breton; and, unless its strata extend far to the north under the Devonian, it is not to be expected that Meguma rocks would be found on the island. A small circular area of this age is, indeed, mapped in southern Cape Breton (Geol. Surv. Can., doc. 203), occupying only about one-fourth of a square mile, and surrounded by pre-Cambrian rocks; but what evi-

dence there is for correlating it with the Meguma I do not know.

All that can be said definitely at present, upon the subject of original extent, is that the character of the sediments gives no indication of the proximity of any natural margin, and the former lateral extent was probably much greater than now exposed, even were the strata straightened out and the folds eliminated.

Evidence as to greater original thickness is of four classes, none of which gives definite quantitative results. The first is the extent of younger sediment composed of material which may have been derived from the Meguma. No measurements have been made which would justify giving figures on this matter. But the area and thickness of the lower Carboniferous conglomerate in the eastern half of the province, where it is composed almost entirely of Meguma waste in parts, are both considerable. It is very noticeable at Gays River mines, Coldstream, Colchester county, that the conglomerate contains a large amount of one rock not now found as a part of the older series—a dull red sandstone. The rest is readily traceable to the Meguma. This red of course may be Devonian; but there is no evidence that it is, and the boulders at Gays River have evidently not travelled far. Again, there may have been an upper formation in the Meguma, now eroded completely away and preserved in these relics; or the latter may come from a younger era below the Devonian, although we know of none which answer the description.

The second class of evidence as to the former thickness of the Meguma is its structure. The folds are as sharp and well-formed at the present summit as at the bottom; and, except at [illegible] parts which appear to be [illegible] brittle. The whole [illegible] by the series indicate [illegible] the zone of plastic-[illegible] fracture.

[illegible] metamorphism, [illegible] paper. It is [illegible] bottom, and of [illegible] of superin-

cumbent sediment for its growth. Moreover, it is all pre-Carboniferous, and probably considerably antedates that period.

The fourth group of testimony comes from the intrusions. With the exception of dioritic marginal phases and dioryte apophyses, they are all granitic and abyssal. Nowhere does the slightest tendency appear toward a transition to quartz porphyry or aporhyolyte; although the granites cut the highest strata in the series in such manner as to show that they must formerly have extended far higher. This is especially true of the great western massif. The period of intrusion was after almost all the great events in the history of the Meguma had taken place; and this indicates that even at that time there was a very considerable cloak of superincumbent strata. Some of the granite areas are so large as to force the conclusion that they originally extended far above the present summit of the series. The depth of cover needed to allow acid magmas to crystallize as coarse granites must be considerable, as shown by the infrequency of dikes of granite other than as short apophyses.

The conclusion from these various lines of observation is that the Halifax formation must originally have been far thicker than at present, or that it was covered by some thick formation, probably conformable and sharing its history. The great western massif, cutting Siluro-Devonian strata, seems to indicate the latter; but (1) these strata are not of great thickness, and (2) the granites of the Meguma series are almost certainly of more than one age of eruptivity, so that the history of the large mass cannot fairly be taken as representative of the whole. Although there is no direct quantitative evidence, it probably is safe to consider that at least a mile has been stripped from the present highest beds of the Halifax, of which we have not even a vestige left.

Problem of original dimensions: present bulk.—The area now occupied by the stratified rocks of the series is 4,500 square miles. The known thickness alone, if uniform, gives with this area a contents of 22,500 cubic miles before erosion. But measurements across the folds show that the same sediments now exposed, if restored to a flat position, would occupy at least 75 % and probably 100% more area; so that the total bulk of the rocks now represented, but restored to an even thickness may be conservatively estimated at 45,000 cubic miles.

What has been lost above and laterally, what lies below the lowest visible strata, and what under the cloak of younger formations to the north, we have no means of knowing. Taking the total present area of the series, however, as 8,000 square miles including that part replaced by granite, the total cubic contents when restored to a condition of horizontal stratification would be approximately 88,000 cubic miles of rock.

If examined from the standpoint of the amount of erosion necessary to produce the series, even the figures given are seen to be very large. To produce these sediments would require the complete degradation of the provinces of Nova Scotia, New Brunswick and Prince Edward Island, from an alpine condition with high peaks and total average elevation of 9,200 feet to sea level.

Area and time of erosion represented.—Such a history places the series one of the largest almost purely inorganic accumulations known. The time occupied by its deposition was [illegible] great; so great that figures have no value in dealing with the problem. The Goldenville formation evidently was accumulated at a rate not very rapid, as shown by the [illegible] of coarse debris, and relatively small amount of cross-bedding, and at a rate not very slow, indicated by the lack of [illegible] of the strata and the relatively small percentage of [illegible]. The Halifax, even at its present much diminished thickness, may represent more time than the lower formation. The continuity of sedimentation appears to have been unbroken throughout, and this points to one of the longest epochs of continuous deposition, as well as one of the most ancient.

Pre-Meguma land position.—There is little evidence as to the position and character of the land mass from which the Meguma series was derived. Of the sandstone and pelytes, it cannot be said that [illegible] finer or coarser in any direction [illegible] and there occur throughout the [illegible] [illegible]rated, both stratigraphically and [illegible] instances of cross-bedding, which [illegible] the direction of the land, are [illegible]; but much remains [illegible].

The [illegible] southwestern end of the series [illegible] and it is a fair

assumption that this marks a shoreward direction in part, and that a portion of the pre-Meguma land mass lay to the south and west of the west end of the province. The size of the boulders in the Yarmouth conglomerate indicates a transportation by no means long. The cross-bedding seen in the west, as far as it has any weight, points to the same direction of land, the south. On the other hand, the structure of the eastern part of the series is of such type as would readily have resulted from the folding of sediments marginal to a land mass to the north.

There is no evidence as to the proximity of the old shore lines to any known points, if we except the large boulders in the Yarmouth conglomerate; and when it can be proved conclusively whether or not these are basal, they may be of greater service.

Pre-Meguma land: composition.—As to the character of the material forming this land mass, two indefinite lines of evidence are available. The first is the chemical character of the sediments. This is moderately acid to intermediate, depending upon the situation. The silica of the quartzytes is in part offset by less acid minerals such as chlorite. A large number of rocks could have furnished detritus of such nature.

The second class of evidence is the mechanical nature of the strata. The pebbles at Mt. Uniacke and Waverley, if there be any, are slate. Bailey's reference at Pubnico is quartzyte, and my own confirms it for the general region. The pebbles near Lockport, mentioned by Bailey as "quartz," may be quartzyte; and those at Port la Tour are quartzyte. What the "gray vesicular rock" is, is not known. Thus the only authentic evidence as to kinds of pebbles points to quartzyte as at least a prominent ingredient of the old land, but it cannot have been the only one. Aside from the inherent improbability of one kind furnishing so many cubic miles of detritus, quartzyte, however impure, would hardly account for the several thousand feet of argillaceous material in the slates of both formations. In the lower this is intimately mingled with the sand, the two in many places alternating several times in a foot of thickness; and evidently they came down in the water approximately together.

In addition, there is clastic mica, and the relic of feldspars in places. Granitic rocks would furnish detritus in proportions nearest to these found in the series. No sediments alone would do it, except perhaps a series essentially like the one made from it; and igneous rocks more basic than the granite-rhyolyte series would not furnish the requisite amount of quartz.

In view of the evidence, it may be stated very tentatively that the pre-Meguma land mass probably consisted of granitic igneous rocks; with some sediments, of which we have definite trace in the quartzyte conglomerates and perhaps in some slate conglomerates in the center of the province.

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EROSION ON THE GREAT PLAINS AND ON THE CORDILLERAN MOUNTAIN BELT.

By WARREN UPHAM, St. Paul, Minn.

The subaerial sculpture of great land areas is not less worthy of attention than marine sedimentation, upheaval, and volcanic action, by which the lands were originally formed. It is also very interesting to follow the great courses of drainage, and to note the marine and lacustrine deposits that have been derived from the wear and waste of continents.

In the region here considered, namely, the north part of our Great Plains and the part of our Cordilleran belt where it is crossed by the Northern Pacific, Great Northern, and Canadian Pacific railways, the physiographic history is comprised in the Tertiary and Quaternary eras. During the much longer ages of Paleozoic and Mesozoic time, from the Cambrian period to the Cretaceous, inclusive, the site of the Yellowstone National Park and a vast region to the north and west were covered by the sea, with practically continuous and conformable sedimentation, sometimes at abyssal depths where little deposition took place through long periods, and sometimes in shallower water receiving plentiful tribute from adjoining eroded lands.

The Cretaceous sea of that region, in which its latest sediments were laid down, stretched eastward over Manitoba and the greater part or all of Minnesota, to the area now occupied by the west end of lake Superior. Though the strata then formed have been mostly or wholly eroded and removed from a tract 100 to 200 miles wide along the eastern margin of the Cretaceous marine area, its fossiliferous beds are found in place by H. V. Winchell so far east as on the Little fork of Rainy river* and on the Mesabi range.† Thence west to the Rocky mountains, an expanse of deep Cretaceous strata, mostly shales, was uncovered from the sea at the end of that period, and has since been subject to erosion.

At first a vast flat and monotonous plain, this expanse has lost hundreds of feet at the east and thousands of feet at the

* *Geol. and Nat. Hist. Survey of Minnesota*, Sixteenth Annual Report, for 1887, pp. 403-9, 431, 434.

† AM. GEOLOGIST, vol. xii, pp. 220-223, Oct., 1893.

west by denudation; but the surface yet retains so much semblance of its original flatness as to be commonly called "The Plains." Like all the interior basin drained by the Mississippi, Missouri, St. Lawrence, and Nelson rivers, between the Appalachian and Cordilleran mountain belts, the Plains, 800 miles wide and of much greater extent from south to north, have been exempted from the throes of mountain building. Their only oscillations of altitude have been epeirogenic, in marked contrast with the grand orogenic movements which formed the Cordilleran ranges.

At the beginning of the history of the Plains, one of the mighty mountain-building and continent-making epochs gave rise to the principal ranges of the Rocky mountains, the frontal parts of the Cordilleran belt, which were folded and uplifted near the end of Cretaceous time. As the chief orogenic revolution producing the Appalachian belt of mountains, from northern Alabama to New Hampshire and Maine, coincided with the close of the Paleozoic era, so the end of the Mesozoic era witnessed the upheaval of the sea bed to form the Great Plains, the birth of the Mississippi flowing at the foot of their eastward slope, and the thrusting up of mountain ramparts along all their western border. The sites of Helena, Butte, and Great Falls, cities of the mountains and plains of Montana, then emerged from

"The stillness of the central sea."

Ten years ago I published a paper from my studies of "Tertiary and Early Quaternary Baseleveling in Minnesota, Manitoba, and Northwestward,"* and ever since I wished to cross the western half of our continent, until opportunity came last year. In my journey over the Plains and the broad Cordilleran region of mountains, valleys, and basins, the vastness of Tertiary erosion was more fully appreciated, and I was impressed with the multitude of the mountain ranges, rather than by their hight.

In Montana, Idaho, and Washington, these mountains are of the same order, in respect to altitude above the land at their base, as the White, Green, and Adirondack mountains, instead of representing the most lofty mountains of all the world,

* Amer. Geologist, vol. xiv, pp. 235-246, Oct., 1894; *Bulletin, Geol. Soc. of America*, vol. vi, 1894, pp. 17-20.

as the European Alps, the Caucasus, and the Himalayas. But with those latest formed mountains, which together may be named the Eurasian mountain belt, should be classed, in the same first rank as to hight, and of similar late Tertiary and Quaternary time of uplifts, other parts of this very long and wide Cordilleran belt, such being Mt. St. Elias and its neighbors, the Sierra Nevada of California, and the high Andes.

Attending and following the great folds, faults, and uplifts of mountain ranges through the western side of our continent, which closed the Cretaceous period and began the Eocene, so bridging the transition between the Mesozoic and Tertiary eras, volcanic intrusive and eruptive rocks added greatly to the mountain masses of some tracts, as in the Yellowstone Park and in the Cascade range, and spread over very large plain areas in the basins of the Snake and Columbia rivers.

During the Tertiary and Quaternary eras, this western half of our country and of Canada, newly raised from oceanic depths into plains and mountains, has undergone much erosion; and the rivers have borne thence the detritus from this vast area, depositing it mostly beyond their mouths in the sea. Quantitative estimates of the amount of this erosion, and consequently of the offshore sedimentation, are afforded from the Plains by the Turtle mountain, on the international boundary of North Dakota and Manitoba, and by the Crazy and Highwood mountains in Montana. Farther to the west, such estimates may be taken from the valleys and canyons of the wide Cordilleran belt, and from the fiords of Puget Sound and the coast northward.

Turtle mountain, 40 miles long from east to west and about 25 miles wide, rises 300 to 800 feet above the surrounding eastern part of the Plains, the tops of its highest hills being about 2,500 feet above the sea. Under a veneering of the glacial drift, which probably averages 50 to 75 feet in thickness, this wooded highland consists of nearly horizontally bedded Laramie strata, chiefly shales, with thin seams of lignite. It testifies that a thickness of 500 feet, or more, of Laramie and Montana (Fox Hills and Ft. Pierre) strata has been eroded from the surrounding region.*

* "The Glacial Lake Agassiz," *U. S. Geol. Surv., Monograph XXV*, 1895, pp. 85, 173.

Around the Crazy mountains, prominently seen from Livingston, where the Northern Pacific railway branch for the Yellowstone Park leaves the main line, much deeper general erosion of the Plains has taken place, to the vertical extent of 3,000 to 5,000 feet. This group of mountains, about 30 miles long from south to north and 10 to 20 miles wide, rises in its highest peak 11,178 feet above the sea, being 5,000 to 6,000 feet above the adjoining prairies. The structure of this mountain mass has been thoroughly studied by Dr. J. E. Wolff, who finds that it consists of late Cretaceous or early Eocene strata, mostly soft sandstones, nearly horizontal in stratification, named the Livingston formation, intersected by central volcanic outflows and a network of innumerable radiating dikes.* The more enduring igneous rocks have preserved the mountain group, while an average denudation of nearly or quite one mile in vertical amount reduced all the surrounding country to a baselevel of erosion. Alluvial sedimentation on this area was rapid and deep while the neighboring Rocky mountain ranges, west of these Plains, were being uplifted; and the ensuing Tertiary erosion in baseleveling here greatly exceeded its volume from the country eastward.

A hundred miles distant thence to the north, the Highwood mountains, about 30 miles east of Great Falls, having a hight of 7,600 feet above the sea or about 3,500 to 4,000 feet above their base, are described by Prof. W. M. Davis as displaying a similar structure, and therefore testifying likewise of great denudation.†

It seems a reasonable estimate that the average depth of erosion from all this northern part of the Plains, stretching from the Red river valley to the Rocky mountains, is at least 1,000 feet. Such a vast volume of detritus was carried away by the predecessors of the Missouri and Saskatchewan rivers and their tributaries during the Tertiary era, to be mostly borne forward to the sea by the great streams which represented the Mississippi and Nelson rivers during that time. Thus it is seen that, if the Tertiary era had a duration of about 3,000,000 or 4,000,000 years, as estimates of the ratios of geolo-

* *Bulletin, Geol. Society of America*, vol. iii, 1892, pp. 445-452.

† Mining Industries of the United States, *Tenth Census*, vol. xv, pp. 710, 737, 745. See also the *U. S. Geologic Atlas*, Folios 1, 56 and 55, respectively the Livingston, Little Belt Mountains, and Ft. Benton Folios, by WALTER H. WEED, mapping and describing these two mountain groups.

gic time by Dana, Walcott, the present writer, and others, have indicated, the mean rate of denudation on the Plains throughout that era was approximately the same as now, or an average of one foot in three to four thousand years.

Extensive Tertiary formations in the southern part of the Mississippi basin and along the Gulf border accord well with the foregoing estimate of erosion and resulting deposition. But northward, in the Hudson bay region, Tertiary beds are wanting, which, with the similar general absence of Tertiary marine strata about the northern Atlantic and Arctic shores of our continent, implies for that great land area an altitude throughout the Tertiary era above that of the present time. We may infer that the epeirogenic and orogenic movements originally forming the Great Plains and the Rocky mountains elevated this region much above its present hight; that during Tertiary time the Plains were cut down and mainly base-leveled, having at last, in the Pliocene period, only a moderate hight above the sea, so that their vast expanse was mostly reduced by its streams to a mature peneplain; that in the early part of the Quaternary era it was again greatly uplifted, by another grand but slow epeirogenic movement, attaining its present eastward slope; and that during the same time, and before the culmination of the Glacial period, the broad flat valley of the Red river of the North, and of the large lakes in Manitoba, was formed by stream erosion of the former eastern edge of the Plains, or, as we may better say, of the continuation of their Cretaceous area.

Beneath the waters of Hudson bay and strait and of the North Atlantic lies the great tribute carried from the Rocky mountains and the Plains by the Tertiary and early Quaternary streams that now live anew, since the Ice age, as the Saskatchewan, Red, and Nelson rivers. From the depths of fiords and of submarine valleys, as those of the St. Lawrence and Hudson rivers, we know that this region was raised to a preglacial altitude of 3,000 feet, or more, higher than now, probably giving the cold and snowy climate which induced glaciation.

On the Cordilleran belt farther west, and along the Pacific border, far more complex conditions of erosion and marine deposition characterized these eras, which I hope to consider in a later paper of this series, dealing especially with the Puget Sound fiords.

ON THE PARAMORPHIC ALTERATION OF PYROXENE TO COMPACT HORNBLENDE.

By C. H. Gordon, Seattle, Wash.

A careful examination of the evidence thus far advanced to prove the derivation of compact hornblende from pyroxene is not altogether convincing since most of the phenomena appealed to may be equally well explained on the theory of synchronous growth. Such for example are the occurrences cited by Hawes,* Irving, Van Hise† and others, of augite and compact hornblende side by side, or the latter developed in a zone about the augite Later G. H. Williams‡ refers to the evidence adduced by these writers as lacking in proof, and presents a case where a core of hypersthene is surrounded by a zone of compact brown hornblende, tongues and shreds of the latter extending from the outer rim all through the hypersthene core. Emphasis is also placed on the manner in which the minerals insensibly grade into each other, and on the presence of fine twinning lamellæ which cut sharply across the minerals.

Commenting upon this professor Iddings in his paper on the rocks of Electric peak and Sepulchre mountain, says:§ "It is self-evident that thin edged portions of minerals with similar indices of refraction, which wedge out against one another within the space of a rock section appear to pass into one another by insensible gradations of color. This can be observed in the case of inclined contacts between hypersthene and feldspar in which case there is no suspicion of an actual transition of substance or intermediate stage of chemical character. There is no direct evidence brought forward in the paper cited to show by the crystal outline of the mineral that the original form was that of pyroxene as in the case of uralite. The whole argument seems to the writer to hang on the fact that the hornblende penetrates the pyroxene in tongues and shreds in which respect it resembles the paramorphism of pyroxene to uralite. From the writer's acquaintance with instances of undoubted

* *Mineralogy and Lithology of New Hampshire*, pp. 57, 206. Plate VII. Fig. 1, 1878. Hawes, G. W.

† *Geology of Wisconsin*, vol. iii, pp. 170, 1880. *Amer. Jour. Sci.*, vol. 26. 3rd, Ser. p. 27. *Ibid*, vol. xxvii, 3rd Ser. p. 130. "Copper Bearing Rocks of Lake Superior," *U. S. Geol. Surv. Mon.* X, p. 253.

‡ *Amer. Jour. Sci.*, 3rd Ser., vol. xxviii. p. 259.

§ *U. S. Geological Survey*, 12th Annual Report. Pt. I, pp. 610, et seq. Plate L, LI

intergrowths of hornblende with other minerals the last mentioned argument for the paramorphism of compact hornblende from pyroxene does not seem to him to be sufficient. . . . In cases where augite is surrounded by or appears to pass into compact hornblende and neither mineral exhibits its characteristic crystal outline in any part of the rock under investigation and the rock is unaltered the primary or secondary nature of either mineral may be questioned: for each mineral may be the result of the primary crystallization of the once molten magma from which either of the two may separate before the other, or either may be the result of the alteration of the other, since the change of compact hornblende to compact augite occurs in the rocks already described." From the study of the synchronous development of various rock-making minerals in pumiceous glassy lavas it is evident that caution must be used in referring occurrences of parallel intergrowth to paramorphic changes.

Lawson* refers frequently to the presence of a lighter colored core in the hornblende as evidence of derivation from augite, while Winchell† has described with a like interpretation occurrences of dark green hornblende surrounded by or intimately intergrown with colorless portions, the former being by him considered as occupying the space of the original augite, and the colorless portions as having formed at the same time but entirely free from the influence of the augite. This controverts Williams' view that these so-called zonal hornblendes are the effect of dynamic action, as also that of Van Hise that they represent secondary growths.

Briefly summarized the evidence commonly adduced for asserting the derivation of compact hornblende from augite is as follows:

1. The zonal arrangement of hornblende around augite and the presence of cores or fragments of augite in hornblende individuals, (Hawes, Irving, Van Hise, Lawson, Winchell).

2. The intimate intergrowth of the two minerals (Williams).

3. The imperceptible gradation into each along their common boundary (Williams).

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* Lawson, A. C., *Ann. Report Geol. Surv. Can.*, New Ser., vol. iii, part 1, p. 125F.

† Winchell, N. H., *Geological Survey of Minnesota*, vol. v, 583.

4. The presence of a common twinning plane (Williams).

5. Differences in the coloration of hornblendes; colorless within with dark green zone without (Lawson); dark green within surrounded by a colorless zone or the two intimately intergrown (Winchell).

With the exception of the last all the phenomena thus far considered may be paralleled in the igneous rocks in circumstances which leave no doubt of the primary character of the hornblende as shown by professor Iddings in the rocks of Electric peak and Sepulchre mountain. There is no reason to suppose that a like process of synchronous development may not have taken place in the recrystallization of the gneisses and other metamorphic rocks. In support of this is the occurrence described by the author* where the augite and hornblende appear as independent growths. Their idiomorphic form and their relations to each other and to adjoining minerals suggest independent growth. As against the hornblende being of magmatic origin we may note (1) its occurrence in the rock which has suffered most from dynamic forces, and (2) the absence of idiomorphic hornblende in the least altered rock. While it may be assumed that the elements of hornblende originally crystallized as augite it is evident that the change here is not one of paramorphism, but perhaps a more or less complete dissolution of the augite and a recrystallization of both minerals.

Whether or not the conclusions in the above cited cases are correct does not now concern us. In many and perhaps in all, the inference seems a reasonable one, but it remains an inference only, the evidence offered lacking the elements of convincing proof. Nor is such readily forthcoming owing to the lack of criteria whereby cases of derivation may be clearly distinguished from those due to synchronous growth as Iddings has pointed out.

There is [illegible] however, that may be regarded [illegible] hornblende bands [illegible] the augite. In the author's [illegible] Canada [illegible] cases were observed [illegible] the conclusion

* Syenite [illegible] Region of Ottawa [illegible] Canada. *Bull.* [illegible]

of alteration irresistible. In some cases areas of compact hornblende directly associated with the bordering bands of hornblende and evidently identical with them appear at intervals within the fractured zone. The hornblende occurs chiefly in that portion of the crystal which has suffered most from crushing. Standing alone this latter fact could not be regarded as conclusive evidence of alteration since the position of the fracture may have been determined by the presence of original hornblende intergrown with the augite, but taken in connection with the bands bordering the fracture the whole seems to offer conclusive evidence of alteration.

In descriptions of the crystalline schists there is a widely prevalent tendency to ascribe all the compact hornblende to the paramorphic alteration of augite on what, in view of the foregoing, seems to be insufficient data, and sometimes pure assumption. Without touching the validity of such views we would suggest that there is need of caution here and that the cause of petrography will be promoted by distinguishing clearly between cases that are reasonable inferences only and those that can be conclusively established; while statements based on pure assumption should be avoided.

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CONTRIBUTIONS TO MINERALOGY.

By JOHN EYERMAN, Easton, Pa.

I. SOME ZEOLITES FROM MOORE STATION, NEW JERSEY.

This locality, which is situated a few miles south of Lambertville along the Delaware river, bids fair to become as famous as the historic Bergen tunnel. The opening is operated by the Delaware River Quarry Co., and the material quarried is used chiefly for road making and ballast. The rock is an overflow of plagioclase hornblende and pyroxene.

Besides the zeolites, stilbite, natrolite, mesolite, and scolecite, there are pecolite, datolite, apophyllite, prehnite, light yellow calcite (scalenochedra common and of fair form up to 50 mm.) epidote, cuprite, chrysocolla, pyrite malachite and opal.

STILBITE: This is quite abundant and generally in large masses of crystals. Sheaf-like crystals and globular-radiat-

ing forms predominate, although the orthodome and prism and pinacoids are frequently found; the former measure up to 35 mm., the single crystals up to 15 mm. Fan-like radiations incrusting the rock are quite common.

Colors: milky white, gray, yellow, salmon, red-brown and brown

Analyses, *a*, yellow: *b*, red-brown: *c*, grayish-white: *d*, flat radiations on granite from McKinnon's quarry, Germantown, Pa.

	a	*b*	*c*	*d*.
G	2.209			2.197
SiO_2	58.53	57.00	57.40	55.10
Al_2O_3	15.84	14.97	16.95	14.18
Fe_2O_3		2.08		
CaO	8.02		8.00	9.40
Na_2O	.63		.54	2.70
K_2O	1.65			.40
H_2O	14.67	16.69	16.87	18.60
	99.34		99.76	100.38

NATROLITE: Less common than stilbite, occurring in most beautiful snow-white radiating acicular crystals up to 15 mm. in length; base almost invariably of white calcite. An analysis afforded:

G.	2.228
SiO_2	47.80
Al_2O_3	27.19
CaO	1.50
Na_2O	11.62
K_2O	1.68
H_2O	9.09
	99.78

PREHNITE: Generally occurs massive in narrow seams; crystals rather rare; color Nile green:

Analysis of prehnite.

G.	2.952
SiO_2	43.25
Al_2O_3	20.20
Fe_2O_3	4.87
CaO	26.70
Na_2O	.50
H_2O	4.38
	99.14

II. The Easton Locality.

The minerals of the syenite ridge and contiguous rocks have long been known to collectors. This belt, appearing in Warren Co., N. J., crosses the Delaware river a quarter of a mile above Easton and extends southwesterly a distance of three miles, thinning out at both ends. A belt of serpentine forms the south contact between the syenyte and a gray blue limestone of uncertain age. North of the syenyte is found the same blue limestone which forms the southern contact. The minerals occurring here (those in italics being rarely found) are graphite, *molybdenite* (in precious serpentine), *chalcopyrite, chalcocite,* pyrite, *fluorite, galenite, gypsum,* quartz, limonite, hematite, calcite, aragonite, *hydromagnesite, barite, celestite, strontiano-calcite,* malachite, zircon* tremolite, actinolite, asbestus, mountain leather, pyroxene, coccolite, sahlite, nephrite, serpentine, bowenite, tourmaline, *topaz,* biotite, phlogopite, talc, orthoclase and prochlorite.

Orthoclase: Being an essential constituent of the rock it is more or less common massive. Good crystals are occasionally found and two analyses are given, *a* creamy white, from Marble Hill, N. J.; *b,* light-red crystal, from the ridge north of Easton.

Analysis of Orthoclase.

	a	*b*
G.	2.609	2.597
SiO_2	65.73	66.14
Al_2O_3	17.21	18.96
Fe_2O_3	2.58	.62
CaO	2.69	.08
K_2O	9.59	10.79
Na_2O	2.41	3.00
ign.		.40
	100.21	99.99

Tourmaline: Generally occurs massive, imbedded in quartz, above the devil's oven, Bushkill creek, west of Easton. Good crystals up to 60 mm. showing *a o m* planes are occasionally found, and an analysis of one of these crystals is appended. Some brilliant black striated crystals 40 mm. long have been found at Marble Hill, imbedded in orthoclase.

* I have in my possession some dark brown crystals doubly terminated of fine form 15 mm. long imbedded in biotite.

Analysis of Tourmaline.

G	2.991
SiO_2	35.57
TiO_2	.18
B_2O_3	10.10
Al_2O_3	24.72
Fe_2O_3	1.17
FeO	9.40
CaO	3.42
MgO	8.29
Na_2O	2.10
K_2O	.40
Li_2O	tr.
H_2O	4.23
F.	undet.
	99.58

BIOTITE: Very common, usually in small plates disseminated throughout the rocks of the serpentine belt. Good crystals are occasionally found and one large one in my possession measures 50 mm. in length. The smaller and more slender crystals are the most common. *a*, silver-white; *b* light brown; *c*, dark brown.

Analysis of Biotite.

	a	*b*	*c*
G.	2.712		2.880
SiO_2	41.07	41.12	40.32
Al_2O_3	23.34	17.23	18.03
K_2O_3	4.35	3.14	5.80
MgO	23.00	24.00	24.79
CaO		.89	.46
Na_2O	1.00	.42	
K_2O	0.30	9.50	10.50
H_2O	.26	3.56	.25
	99.92	99.86	100.15

PROCHLORITE: Analyses of decomposed and altered olive-green (*a*) and light-green (*b*) material from William's Bush-hill quarry afforded:

	a	*b*
G	[illegible]	2.533
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]

MgO	34.20	31.20
H_2O	12.60	12.69
	99.10	99.48

AMPHIBOLE: Many varieties are found, all more or less massive. Analyses of actinolite (*a*) in grayish-green striated crystals from the Reservoir quarry, and asbestus (*b*) in long pure white fibres from the Delaware River quarry resulted:

	a	*b*
SiO_2	54.35	55.25
FeO	2.27	2.18
CaO	13.43	12.66
MgO	28.05	30.19
ign.	1.25	
	99.35	100.28

SERPENTINE: A large number of analyses have been made, three of which are here recorded:

a, Pure white variety, resembling *c* in association, color, texture and grain; *b,* An altered aluminous variety, foliated; both from Williams' Delaware quarry, and *c,* The socalled meerschaum from Middletown, Delaware Co.

	a	*b*	*c*
G.	2.363	2.718	
SiO_2	44.21	39.83	44.58
Al_2O_3	2.72	6.39	tr
FeO	.52	1.71	2.13
CaO	.24	.07	tr
MgO	40.55	39.92	39.49
Na_2O		1.11	
H_2O	12.42	10.23	12.91
	100.66	99.26	99.11

Of the many minerals found in the serpentine belt, as might be expected, the majority are more or less altered, and pseudomorphs are not uncommon.

III. GARNET.

In my account of the mineralogy of the French Creek mines (Trans. N. Y. Acad. Sci., viii, 1889) I mention lime-iron garnets as occurring in considerable quantities at shaft No. 1. These occur in large groups of dodecahedral crystals with truncated edges, single crystals varying in size from 5 to 25 mm.; color very dark brown; fracture resinous.

(*a*) French Creek. This variety is also fairly abundant at the Franconia Iron mine a mile and a half from Sugar Hill P. O., N. H., associated with epidote and hornblende (*b*). I also give an analysis (*c*) of the variety almandite containing considerable manganese and found in large dodecahedral crystals with truncate edges at Bishop's Mill, Middletown, Delaware Co. Color: dark brown.

Analysis of garnets.

	a	*b*	*c*
G.	3.710		3.991
SiO_2	35.42	35.65	36.22
Al_2O_3	8.51	3.76	24.58
Fe_2O_3	21.04	25.59	
FeO			30.71
MnO	0.88	1.82	8.97
CaO	25.07	32.96	
	100.52	99.78	100.48

IV. GENTH'S UNDESCRIBED ZEOLITE.

Dr. F. A. Genth in his *Mineralogy of Pennsylvania* (p. 110.) gives an analysis of an undescribed zeolite having an inclusion of calcite (*b*). Several years ago I obtained a small quantity of material, consisting of badly distorted crystals, but undoubtedly tetragonal and resembling the apophyllite from French Creek. Color: white, transparent; lustre: vitreous. H. [illegible] G. [illegible]. B.B. easily fusible, becoming opaque, and [illegible] reaction. Calcite not present.

[illegible]

		b
[illegible]	[illegible]	43.36
[illegible]	[illegible]	28.78
[illegible]	[illegible]	10.05
[illegible]		.68
[illegible]		1.38
[illegible]	[illegible]	15.52
	[illegible]	[illegible]

[illegible] different from the [illegible] and better developed [illegible] it to any known [illegible] new. The material [illegible]

IN THE MATTER OF THE PERMIAN FISH MENASPIS.

By Bashford Dean, New York.

PLATE II.

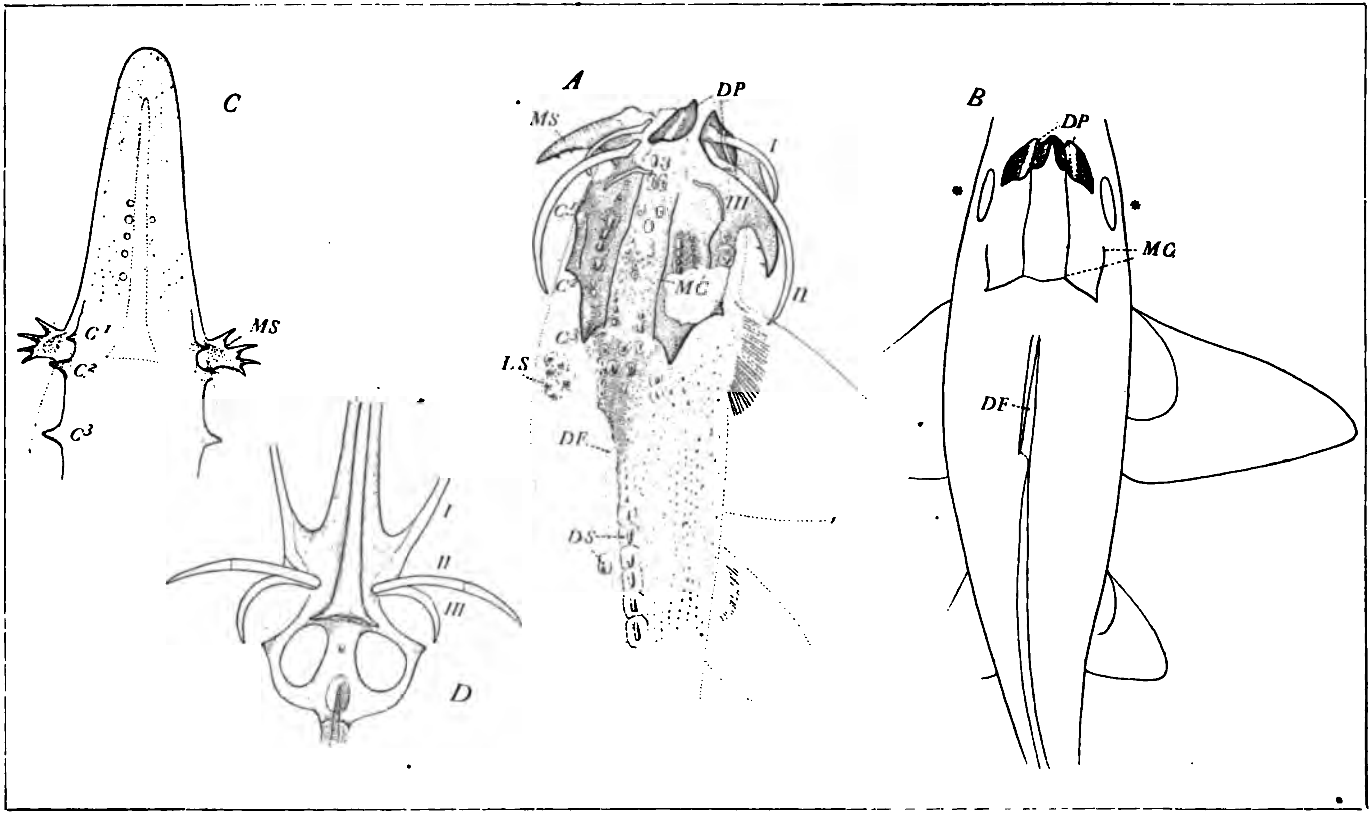
Among fossil fishes Menaspis has been the source of considerable discussion. For, while it belongs, generally speaking, within the interesting circle of the more ancient sharks, it shows structures which are so puzzling one does not wonder that very discordant views have been held regarding its position in the system of fishes.

Thus, Ewald early maintained that it was akin to Cephalaspis. Jaekel, on the other hand, contended that it represented a "Trachyacanthid," that is, a "placoid" connected with Cochliodus, Oracanthus, Sandalodus, Onchus.* Among other experts, A. Smith-Woodward has regarded it as an armored shark of "some unknown group," and Reis has placed it near the xenacanthids, *i.e.*, ichthyotomous sharks, but later emphasized its chimæroid characters. The discussion, however, has subsided during the past decade, and it is only in the light of an undescribed fossil and after a re-examination of the valuable chimæroid material in the British Museum, and in the Palæontological Museum in Jermyn street, that the present writer has been led to reopen the question of its relationships.

Menaspis is remarkable on two main grounds. The head region, Fig. 1A, is surmounted by what appears to be a series of paired spines (some of which are of a kind apparently unknown in any fishlike vertebrate) which pass from the region of the mouth backward on either side in a graded series. Second, the region which has been regarded as the trunk is enclosed in broad, almost plate-like tubercles, of which a posterior pair protrudes backward, Fig. 1A, C^3, suggesting somewhat the posterior rim of the shoulder armoring in an Ostracophore. These features, it may be remarked, are fully taken into account by professor Jaekel in his description (1891) of the important example of the fossil noticed by Giebel and Ewald.

*To Jaekel, in short, it typifies a stage in the phylogeny of fishes where the dentition was plate-like and permanent, and where the dermal armoring was gradually becoming reduced in transition from the plated palæozoic fishes to the shagreen coated sharks. He later ('99) shifts his ground and admits that Trachyacanthids may occupy a position intermediate between sharks and chimæroids.

[illegible] the fins, as [illegible] may be re- [illegible] are widely [illegible] during [illegible] interpre- [illegible] ximately [illegible] denud- [illegible] the op- [illegible] trunk pre- [illegible] In the second regard, it will [illegible] position with respect



PERMIAN FISH, MENASPIS.

to the head.* According to Jaekel's interpretation, on the other hand, a large gap must have existed between the head and the pectoral region, and consequently, there was present, or might have been present, a greater number of gills in this form. One observes, furthermore, that in the present rendering the ventral fin occurs in the position in which it usually occurs in shark-shaped fishes. In Jaekel's interpretation, on the contrary, they must have occupied a position far back on the trunk, in the neighborhood, in fact, of the caudal fin.† Jaekel infers that a dorsal fin could hardly have been present in Menaspis. If, however, the present explanation is just, a dorsal fin may well have existed, although it has not been preserved in the type fossil. Its position is suggested by a dotted line in the restoration, *DF*, and the line of shagreen denticles shown in the fossil may have passed beside it, as in the case of chimæroids, both living and fossil.

The dental plates shown in the Berlin specimen, together with the entire fossil, will, it is to be hoped, be shortly figured by professor Jaekel, so that their more definite relations (*e.g.* to Deltodus and similar forms) may be accurately determined. I may, however, be permitted to note that they are strikingly chimæroid in character, reminding one of Rhynchodus, although showing no conspicuous tritoral areas. In any event, the number of these plates is but four, as in the Devonian chimaeroid.

Menaspis and its Relation to Chimaeroid Fishes.

If Menaspis, a Permian form, be closely related to chimæroids, it possesses the interest of being the earliest representative of this ancient group whose body structures are preserved. And that it is essentially chimæroid is shown from the following grounds:

(1) Resemblance to Myriacanthids.—These Mesozoic chimæroids possess a series of lateral head spines which agree essentially with those indicated by *M.S.*, *C* C^2 and C^3, in the present restoration, Fig. 1A. Especially convincing is the similarity of the anterior lateral spines in myriacanthids and Menaspis. In the later form, however, the extreme rim of the

* The left pectoral fin in the first specimen appears to have been bent under the body, and has been partly exposed by the breaking away of the upper portion of the fossil, judging from Jaekel's figure.

† He does not explain, however, how this tallies with his view that Menaspis was ray-like in habit.

spine is provided, naturally perhaps, on account of its more recent appearance, with more highly differentiated denticles. *Cf. Fig. 1C.* The lateral head spine of myriacanthid has hitherto been regarded as a "dermal plate"* and its projecting denticles have not been perfectly preserved. The writer is, accordingly, greatly indebted to professor E. T. Newton of the Palaeontological Museum in Jermyn street, for the privilege of examining an unfigured specimen of "*Prognathodus guntheri*" (*Myriacanthus paradoxus*), from the classic locality at Lyme Regis, which shows these antero-lateral spines in approximately their natural position. One observes in passing that the spines in this specimen had a well marked basal region ensuring their firm attachment, and we have thus additional evidence for regarding the group of trachyacanthids as an artificial one, Jaekel having maintained that the lateral head spines of Menaspis, which are closely to be compared with the present spine of myriacanthids are practically without basal expansion.

(2) Dentition. The dental plates, as above noted, are four in number, and agree essentially with those of Rhynchodus. One notes, in this regard, the peculiar ridge passing along the buccal face of the plate, which finds its apparent homologue in many chimaeroids. How closely its tritoral elements correspond remains to be determined by histological study. Moreover, as here denoted, the plates agree with those of chimaeroids in their proportion to the size of the head.

(3) Dermal scutes.—These agree in essential characters with those of Mesozoic chimaeroids, notably Squaloraja.

(4) Relations of the mucous canals.—These are denoted in the restoration and will be found to agree essentially with those of chimaeroid. (*Cf.* Fig. 1B.) They are moreover, open canals as in recent chimaeroids.

(5) Characters of the paired fins. The basal elements resemble strikingly those of Squaloraja.

(6) Disposition of the so-called paired head spines denoted by I, II and III in the restoration, Fig. 1A.—These structures, shown by Reis to be fibro-cartilage rather than vaso-dentine, apparently correspond to the so-called lip cartilages of Squaloraja. They are, it is true, unjointed, but from

*Both Woodward and Jaekel have indicated that these spines may have had their position on the sides of the head Oracanthus like.

their rounded bases, as is well shown in the type specimen, they were evidently movable. In point of size, moreover, they best correspond to the elements referred to in Squaloraja. Such structures would, moreover, be apt to take a position dorsal to the antero-ventro-lateral head spines during the process of fossilization.

The above considerations lead us, accordingly, to infer that Menaspis, although showing a number of shark-like features, was an early chimæroid. Its likeness to chimæroid rather than to shark is shown notably in the dentition, in the character and disposition of the lateral head spines, and in the remarkable paired "spines" which may be compared to the "labial" structures of Squalorajid. Conclusive proof of its chimæroid affinities, however, will be lacking until it can be shown that the erectile frontal spine was present in the male (the type specimen may have been a female), and that it possessed a dorsal fin-spine and the peculiar vertebral-column known to have been possessed by chimæroids from mesozoic times. The evidence for the present interpretation of Menaspis is at least adequate, I conclude, to enable us to interpret the most troublesome features of the fossil. It is no longer a nebulous "trachyacanthid" with vague affinities to doubtful early groups, but instead, a form well proportioned. (*Cf.* Figs. 1A and B), after the fashion of shark or chimæroid, but with its major features allying it with the latter group. It is remarkable in the possession of well-marked lateral head spines, and in a series of three pairs of greatly elongated and curiously unsegmented spine-shaped cartilages. In the former regard, agreeing with older chimæroids, it presents more specialized dermal developments than are known to have been developed in the contemporary sharks. In the latter regard it is certainly extraordinary, although, as above noted, somewhat similar structures exist in Squaloraja. In short, we reasonably conclude that in Menaspis there is preserved a Permian chimæroid representing a distinct family (Menaspidæ A. S. W.) provisionally to be placed near the Myriacanthidæ and Squalorajidæ. The larger question of the relationships of the chimæroids need hardly enter into the present discussion. It may be enough to indicate that in the matters of dermal defenses and teeth the Permian chimæroids resemble the contemporary cestraciont sharks.

REVIEW OF RECENT GEOLOGICAL LITERATURE.

Contributions to the Geology of Washington: Geology and Physiography of Central Washington. By GEORGE OTIS SMITH. *Physiography and Deformation of the Wenatchee-Chelan District, Cascade Range.* By BAILEY WILLIS. U. S. Geol. Survey, Professional Paper, No. 19. Pages 101, with 20 plates and 3 figures in the text. 1903.

The first part of this work comprises 39 pages, with seven plates, in which Dr. Smith shows that the region of the Cascade range in Washington, after the eruption of its great lava flows of Miocene age, was reduced by general erosion in the Pliocene period to a low peneplain, which, toward the end of that period and later, was uplifted to form the Cascade range, with great erosion during the uplift and to the present time. These studies supplement the former work of Russell, and confirm his estimate that the maximum vertical extent of the late Pliocene and Pleistocene uplift was about 7,500 feet along parts of the axis of the range.

The uplift appears to have been a broad upward flexure or arching of the earth's crust upon an area averaging about a hundred miles in width and extending from south to north across the state of Washington. On the eastern slope of the range, extensive warping produced broad buttresses, one of which is represented by the Wenatchee mountains, culminating in Mt. Stuart, 9,470 feet high, fifteen miles east of the main crest of the Cascade range.

South of the Wenatchee mountains, minor ridges, from 2 or 3 miles to 10 miles or more in width, running easterly from the Cascade range, were gently arched to hights of 1,000 to 3,000 feet above the valleys; and the Yakima river intersects several of these ridges in its canyons below Ellensburg. This river, like the Columbia in its cutting through the high Cascade range, remains in the same course which it had before the complex uplifts and warping of the Miocene and older eruptive and sedimentary rock formations. The rivers are older than the mountains.

Willis, in the second part of this work, discusses the evidences of these great events in the history of the Cascade region as observed by him in the district of the Wenatchee, Entiat, Chelan, and Methow mountains, eastern buttresses of the great main range, with the valley gorges or canyons of lake Chelan and the Columbia river. He estimates the area of the Cascade uplift in Washington to be about 20,000 square miles. Its time of broad erosion, producing a low peneplain with monadnocks, is named by Willis the Methow stage, and is considered as a part of the Pliocene period. Two stages of uplift, named the Entiat and Twisp stages, are recognized, and are referred to the end of the Pliocene period, with probability that they extend into the Pleistocene period so far as to include the time of accumulation of the continental ice-sheet.

To the reviewer, these uplifts seem capable of correlation, in respect to their time and origin, with the latest uplifting of the region traversed by the Colorado river in its grand canyon, with the latest elevation and eastward inclination of the great plains east of the Cordilleran mountain belt, and with the epeirogenic uplifts of North America and Europe that are made known by their deep fiords and submarine valleys. The broad continental uplifts, contemporaneous with the Cascade orogenic movements, were doubtless the chief cause of the glaciation of both continents. W. U.

Christian Faith in an Age of Science. By WILLIAM NORTH RICE. Crown Octavo, pp. 425. New York. A. C. Armstrong and Co. 1903. Net $1.50.

This book is written from the standpoint of a scientific Christian scholar, whose candor and acumen, the result of scientific training and long and wide study, have brought forcibly to his mind the apparent non-agreements between science and some popular Christian beliefs, and whose Christian faith has spurred him to hold on to the fundamental principles of Christianity. He allows those biblical corrections which have been made necessary by late criticism, but shows that they do not affect the main scope and purpose of the biblical revelation. They are inherent in the human vehicle in which the revelation is made. In other words, the scriptures are not inerrant.

The writer has read the volume entire, with much satisfaction and sometimes with delight. The book is destined to be of great service to the thoughtful scientist, whether Christian or agnostic. It has a wide sweep of discussion. Its style is simple and its statements are candid and fearless. It will not please everyone, for it leans in some parts, so far away from some of the accepted doctrines of the church that strict adherents of the dogmas will denounce it as non-Christian, but its close bond with modern science will win for it and for Christianity the confidence of the earnest and thoughtful of all readers. The author combines in his personality the qualities of an able and fearless seeker after truth in the science of the day, and of a reverent and firm believer in God and his immanence in nature, and in the essentials of Christianity. N. H. W.

The Cambric Dictyonema Fauna of the Slate Belt of Eastern New York. By RUDOLPH RUDEMANN. *New York State Museum Bulletin 69, 1902 (1903).*

This paper is of much interest to American and Canadian geologists as it contains a very full discussion of the relation of the Dictyonema zone to the Cambrian and Ordovician systems.

The author gives an account of the position of this band in Scandinavia, and the elaborate studies Linnarsson, Tullberg, Lundgren and Brögger upon its fossils, and its relation to the Cambrian types below and Ordovician above. "The northern European palæontologists almost without exception, have agreed" to place this band as the "termination of the primordial (Cambrian) fauna."

On the other hand, the English geologists, including Prof. Geikie, still include in the Cam[illegible] the next group (Tremadoc) above this band, though Brøgger [illegible] show that the palæontological evidence is against [illegible] The use of the term Cambrian is based on historical usage, and the acceptance of the Arenig fauna as the base of the Ordovician.

Dr. Ruedemann, [illegible] at Navy island, in the St. John [illegible] that the Dictyonema zone [illegible] he holds with the continental [illegible] the summit of the Cambrian should be drawn at the [illegible] He alludes in terms of ap[illegible] the rocks of the Quebec group in the typical region, but [illegible] misunderstands Ells' table of the [illegible] two lower to Lower Cambrian on account of [illegible] *thompsoni*. Ells' meaning probably [illegible] the pebbles of the conglomerate [illegible] these divisions are not necessarily Lower Cambrian.

[illegible] agree with C. D. Walcott's [illegible] fourth paragraph). [illegible] zone in the lower Or[illegible] of this zone in Scan[illegible] not apply in America.

Dr. Ruedemann [illegible] to divide the Di[illegible] as has been done [illegible] in Sweden.

[illegible] aspect of the D[illegible] The article is pre[illegible] New York by this author.

G. F. M.

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CORRESPONDENCE.

ERUPTION OF MAUNA LOA, 1903. On Monday afternoon, October 5, 1903, as the British ship Ormesery was approaching the west coast of Hawaii, the sea was observed to be boiling as though from great springs beneath the surface. The temperature increased perceptibly and the ship received a shock as if from a tidal wave from the coast. The ship was forced astern by the impact. When land was sighted during the early afternoon of Tuesday, October 6, 1903, a column of smoke was noticed rising from the summit crater of Mauna Loa. First mate Carter who made the [illegible] described the column as about two miles high and three fourths of a mile wide.

Late in the afternoon of Tuesday, October 6, the officers of the Ormesery observed what seemed to be a stream of lava flowing down the

sides of the mountain. The smoke cloud reflected the glow of the fires.

Surveyors Baldwin and Dodge reported what seemed to be a flow among the small cones on the southwest of the mountain, going towards Kahuku along the general line of the flows of 1868 and 1887. This flow was probably lost among the many cones and chasms of that slope as it was soon lost sight of.

The smoke from the summit crater rose in three columns, two small ones and one large one. The columns were aligned almost due east and west. The larger column was on the east towards Hamakua. The columns as they rose united to form one great column that rose to a great hight and in some cases spread out like a great umbrella, the under part reflecting the dull glow of the fires beneath.

Eruption of Mauna Loa, October, 1903.

Many wild stories were circulated, and among them was one, of some ranchmen, that the lava was overflowing the crater wall at the lowest point and flowing down towards south Kana in the general line of the flow of 1859. This report, although verified by two different parties, is probably not correct. The persons (ranchmen) may have seen what appeared to be a flow over the wall, but was simply a crack filled with hot lava that failed to find an outlet. It seemed to be along the line of weakness where you might expect such phenomena.

The lava in the crater showed along a line running through the crater northwest to southeast. There were three principal fire-fountains from which the lava flowed over the crater floor. Steam issued in all directions over the whole crater floor, with an area of (three miles by two and one-half miles) seven and one-half miles. It is said that the crater floor rose 300 feet and then settled back to its old level.

On Monday, December 7th, at 10 p. m., the last glow from the fires was seen and then blackness settled down over the mountain top.

EDGAR WOOD.

To C. H. Hitchcock, Hanover, N. H.

THE DOLOMYTES OF EASTERN IOWA. The experimental work in this investigation was done by Grace D. Bradshaw in the chemical laboratory of Cornell College. The purpose was to determine whether the silica exists in a free condition, or is in the form of a silicate; also to ascertain whether the iron is in the ferrous condition as carbonate, or is in the form of ferric oxide. The rocks abound in many parts of Iowa and belong to the Niagara formation. The stratified character, even in a small field section, is apparent, and the layers differ somewhat in composition as shown by the varying amounts of iron visible in different portions. The rocks are used as building stone to manufacture quick-lime, and in McAdam paving.

To answer the first question as to the condition of the silica six pairs of determinations were made as follows:

(a). A gram of the finely powdered rock was placed in a small beaker, and covered with a watch glass, a small quantity of dilute hydrochloric acid was added and the carbonates were dissolved by carefully heating to the boiling point. The insoluble portion, which is the silica, was filtered off, dried in an air bath, and the weight determined.

(b). A gram of the fine powder placed in a porcelain evaporating dish of 100cc. capacity was treated with dilute hydrochloric acid, and covered with a watch glass. It was warmed on the water bath until there was no further evolution of carbon dioxide. The watch glass was removed and the dish was kept on the water bath until crystals began to appear. Then as the drying continued, the substance was constantly stirred with a glass rod until a fine dry powder resulted. The powder was then moistened with a few drops of concentrated hydrochloric acid, and 20cc. dilute hydrochloric acid (equal parts of concentrated hydrochloric acid and water) and about the same quantity of water were added. The contents of the dish were then filtered and the silica determined. The results for the two methods were as follows:

(a).	(b).
1). 0.78 %	1). 0.75 %
2). 0.76 "	2). 0.90 "
3). 0.81 "	3). 0.85 "
4). 0.87 "	4). 0.91 "
5). [illegible] "	5). 0.87 "
6). [illegible] "	6). 0.73 "

The treatment described under (b) would decompose a silicate, while the method under (a) would not. As the two series of results are fairly concordant, the conclusion is that the silica exists as a fine sand disseminated through the rock. A private communication from W. H. Norton, of the Cornell College department of geology, states that he came to the same conclusion while studying the rock with a petrological microscope. The method described under (a) is simpler than (b), and the work can be done in a much shorter time. It is therefore to be preferred in the analysis of rock of this kind.

2. The condition of the iron.

A gram of the substance was introduced into a flask of 120cc. capacity, fitted with a bulb tube and Bunsen valve to prevent oxidation of the iron. It was dissolved in dilute hydrochloric acid. A few drops of the cooled solution were then withdrawn with a capillary tube and tested with a crystal of potassium ferricyanide. No suggestion of a blue color resulted, showing the iron to be in the ferric condition. This increases the value of the rocks as a building material, as ferrous carbonate is an unstable substance with a tendency to change to the ferric condition. A complete analysis of the specimen resulted as follows:

$CaCO_3$	53.62%
$MgCO_3$	44.96%
SiO_2	0.83%
Al_2O_3	0.25%
Fe_2O_3	0.34%
Total	100.00%

The specimen is nearly a true dolomyte which contains: 54.35 per cent calcium carbonate, 45.65 per cent magnesium carbonate.

This method of analysis was employed: After removing the silica according to (a), a gram or two of pure ammonium chloride was added to the filtrate to prevent the precipitation of magnesium. It was then heated to boiling and a small excess of ammonia added which precipitates iron and alumina. They are determined together and then dissolved in the crucible with warm hydrochloric acid. The solution is treated with caustic potash which precipitates the iron and dissolves the alumina. The iron is filtered off and discarded because it can not be thoroughly washed from the caustic potash. The filtrate is slightly acidified with hydrochloric acid and the aluminum is precipitated with freshly prepared ammonium sulphide. The precipitate when heated in a crucible becomes Al_2O_3. The filtrate from the iron and alumina, containing calcium and magnesium, is heated to boiling and precipitated with an $\frac{N}{2}$ solution of ammonium oxalate, care being used to avoid much excess of the reagent. The precipitate was allowed to stand eight to twelve hours before filtering. The well washed precipitate of calcium oxalate containing also a small quantity of magnesium oxalate was dissolved in warm dilute hydrochloric acid and the solution was made alkaline with ammonia. This precipitates the calcium oxalate and leaves the magnesium in solution. This, with the main portion of the

[illegible] calcium-magnesium [illegible] weight [illegible]

[illegible] Kansas. [illegible] feet thick [illegible] rivers and over fifty [illegible]. In Kansas along the [illegible] defined terraces, one at 20 to 40 feet [illegible] feet higher. The lower [illegible] feet wide overspread with [illegible] gravel [illegible]. The second terrace is about [illegible]. On the higher ground south of Garnett, Kansas, [illegible] at a general elevation of [illegible]. In the valley of the Neosho, at Neosho [illegible] of sand and gravel several feet in thickness, [illegible] feet above the sea, or 30 feet above ordinary water of the Neosho river. Further north, at Burlington, thick gravel deposits are reported, also north of Emporia. Similar deposits [illegible] near the Verdigris at Toronto and above all known high water of that stream. Farther west, on Fall river, at an elevation of [illegible] feet above the sea, and higher than all known water of [illegible] there are deposits of that gravel, the quantity seeming less [illegible] outcrop.

[illegible] into Kansas from the south and near the line of Cowley, [illegible] Chautauqua, Butler and Greenwood, and northwardly towards Emporia, there is a high ridge known as the "Flint Hills." This is much higher than the country lying east or west and is covered with partially rounded [illegible] fragments of flint. The solid strata of this ridge [illegible] except near the line of Elk and Cowley, where [illegible] defined upper Coal Measures strata. The [illegible] of the ridge [illegible] well exposed and [illegible] 100 feet to the crest of [illegible] the country [illegible] for 20 miles to

the general surface west. From the prevalence of Permian strata, I have elsewhere applied the term "Permian mountain" to the ridge. The loose flint is of the upper Carboniferous age and some may be Permian. The ridge varies from 1,500 to 1,700 feet elevation above the sea along the line of Cowley and Elk, the highest point being near the southwest corner of Greenwood county, and 1,565 near the southwest corner of Elk county. The elevations are closely correct being taken when I was in charge of a railroad survey across Kansas in 1879.

These flint beds look to a former period when this country was at least partly covered with water, and in the process of subsiding, the gravel beds were deposited, probably by moving currents originating from the melting in the north of the ice after the close of the Glacial period.

G. C. BROADHEAD.

Columbia, Mo.

PERSONAL AND SCIENTIFIC NEWS.

MR. G. E. CONDRA has been appointed professor of geology at the University of Nebraska.

PROFESSOR W. P. BLAKE of the University of Arizona, is spending the summer vacation at Mill Rock, Conn.

THE DEGREE OF DOCTOR OF LAWS was conferred on T. C. Chamberlin and S. L. Penfield by the University of Wisconsin at the recent jubilee celebration.

DR. F. J. H. MERRILL retired from the position of state geologist of New York June 1, and has opened an office in New York for the practice of economic geology.

PROFESSOR W. H. PETTEE of the department of mineralogy and economic geology of the University of Michigan died suddenly at Ann Arbor, May 26, at the age of sixty-five years.

DR. C. H. GORDON who has been acting professor of geology in the Washington State University during the past year has accepted a call to the chair of geology in the New Mexico School of Mines.

PROFESSOR HENRY LANDES, head of the department of geology in the Washington State University, who has been absent studying in the University of Chicago during the past year will resume his work in Seattle next year.

T. C. HOPKINS, PROFESSOR OF GEOLOGY AT SYRACUSE UNIVERSITY, is doing geological work in California this summer, preparing a bulletin on Structural and Industrial Material for the State Bureau of Mineralogy.

PROFESSOR SAMUEL CALVIN has resigned the position of State Geologist of Iowa. At the meeting of the Iowa Geological Board on the 4th of June the resignation was accepted

to take effect July 1. Dr. Frank A. Wilder, Professor of Economic Geology in the University of Iowa, was elected as Professor Calvin's successor.

The legislature of Connecticut at its last session ordered a geological and natural history survey. The board of commissioners embraces the governor and the presidents of four colleges, viz: Yale, Wesleyan, Trinity and the Connecticut Agricultural College. Professor W. M. Rice of Wesleyan University, has been appointed superintendent of this survey. The present appropriation is $3,000 for two years' work. But there is great probability that this will be increased by the next legislature.

Wanted: Economic Geologist and Paleontologist to take charge of field party investigating stratified economic deposits of coals, irons, clays, etc., of the Philippines, and to perform necessary laboratory and office work in study of fossils and preparation of bulletins and reports; experience in soft coal preferred. Must be graduate, of thorough training, young, and of robust health, and must satisfy United States Civil Service Board of qualifications before appointment. Salary for first year two thousand dollars with field expenses. Leaves of absence granted. Opportunities for original work excellent. Address, giving complete details and recommendations, to avoid loss of time by correspondence, the Chief of the Mining Bureau, Manila, P. I.

At the alumni dinner of the State University of Iowa, the former students of professor Samuel Calvin, to the number of over two thousand, united in the commemoration of the completion of his thirtieth year in a professorship at that institution. The recognition took the form of a costly silver loving-cup, designed especially for the purpose of symbolizing the scientific achievements of the recipient. The cup is a classic Greek vase sixteen inches in hight, and stands on a base of serpentine five inches high. It is adorned with casts taken directly from fossils, with a drainage-map of Iowa, with crossed geological hammers, a microscope, and the more conventional spray of laurel, owl of wisdom and torch of learning,—all in relief. One side bears an appropriate inscription in raised letters.

Professor Calvin was elected to the chair of Natural History in Iowa's university thirty years ago. The "chair" has since been subdivided into four distinct departments, professor Calvin retaining the department of geology. He has been state geologist of Iowa during the last twelve years.

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THE
AMERICAN GEOLOGIST.

VOL. XXXIV. AUGUST, 1904. No. 2.

TECTONIC GEOGRAPHY OF EASTERN ASIA.

Reviews and Translations by WILLIAM HERBERT HOBBS,
Madison, Wis.

PLATES III-IV.

The march of events upon the other side of the planet during the past decade, the imminence of great industrial and commercial evolution, the probability of political changes to which the Russo-Japanese war is the prelude: have served to focus attention upon the geography and only less upon the geology of eastern Asiatic countries. A result of this stimulation of interest in our antipodal regions has been the large number of scientific expeditions which have been fitted out, either with the support or the encouragement of the different governments concerned. The reports of greatest interest from the region, because of the perspective which they afford, are by two masters of generalization in geological science—Professor Edouard Suess,* of Vienna, and Ferdinand Freiherr v. Richtofen,† the great authority upon China, and the professor of Geography at the University of Berlin.

The work of Suess upon the structure of Eurasia would not have been possible at the time his earlier volumes were published (1884). It is therefore a generalization derived from painstaking, careful study of numerous recent reports,

* EDOUARD SUESS. Das Antlitz der Erde, Bd. III (first half), 1901, pp. 1-508. (With general map.)

† FERDINAND V. RICHTOFEN. Geomorphologische Studien aus Ostasien Sitzungsber. d konigl. preuss. Akad. d. Wissensch. z. Berlin.
I.—Uber Gestalt und Gliederung einer Grundlinie in der Morphologie Ostasiens, Bd. XXXIX, Berlin, 1900. pp. 888-925.
II.—Gestalt und Gliederung der ostasiatischen Kustenbogen, Bd. XXXVI, Berlin, 1900, pp. 782-808.
III.—Die morphologische Stellung von Formosa und den Riukiuinseln, Bd. XL, Berlin, 1902, pp. 944-975.

[illegible] note has been [illegible] construction of geo- [illegible] not exposed to [illegible] the larger fea- [illegible] are everywhere [illegible] the knowledge of [illegible] the other he- [illegible] Applying this meth- [illegible]

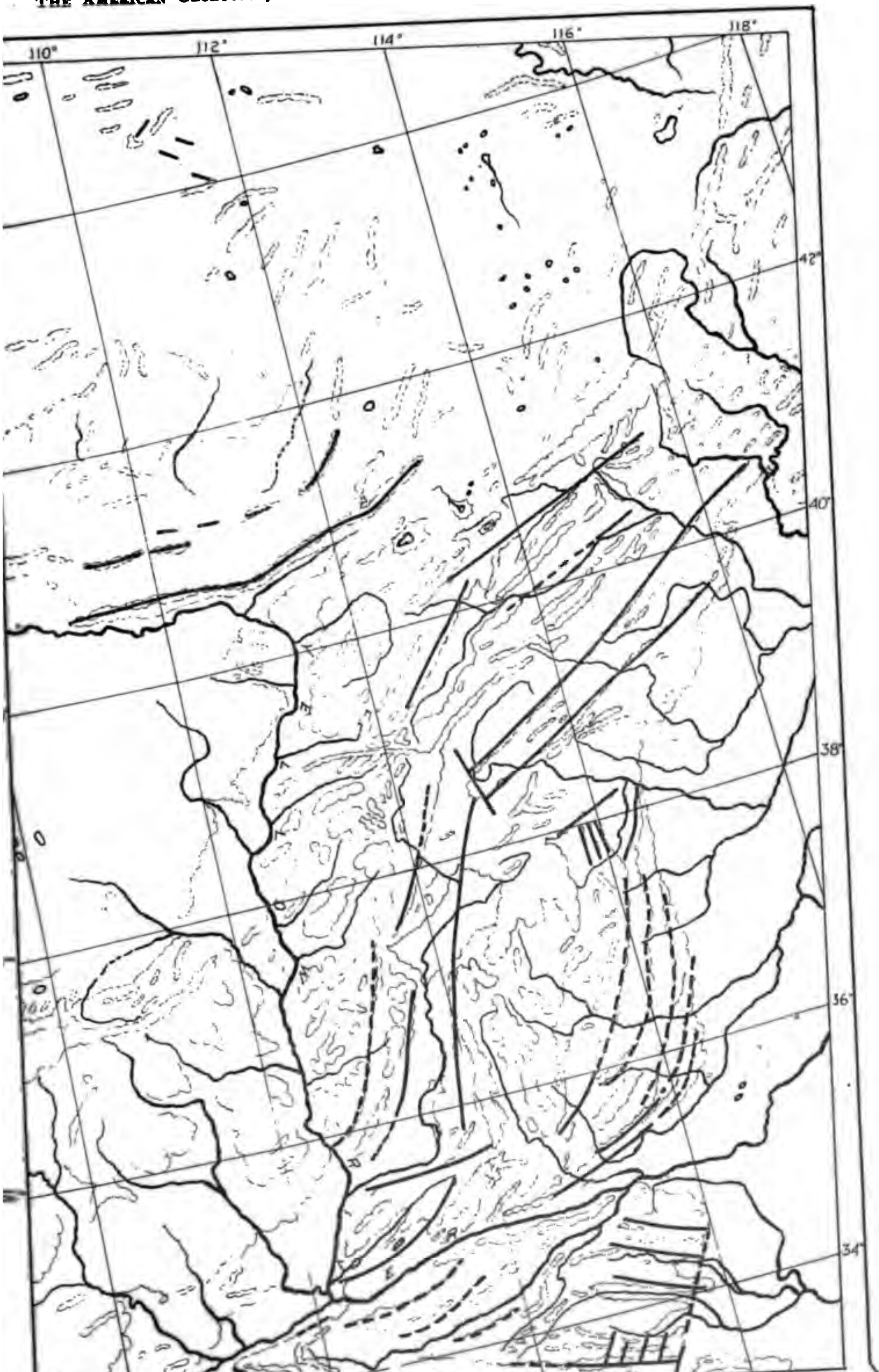

FIG. 1. Reproduction of a portion of Suess' map showing the structural lines for a portion of southeastern Asia.

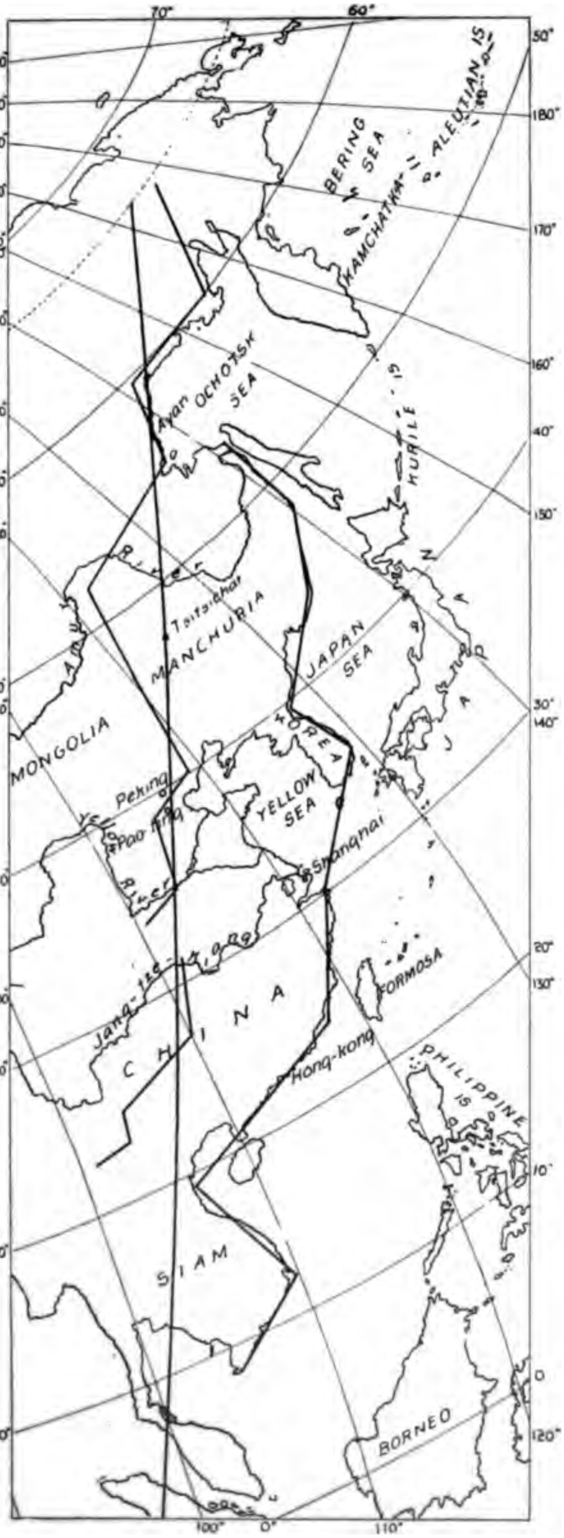

FIG. 2. Outline guide map of eastern Asia, showing tectonic lines and great circle to which they approximate (after v. Richtofen's descriptions.)

"The crescents (*Bogen*) which form these borders, all of them turned to the southward, point to a connection of the parts of this entire extended region, and if one examines the eastern coast of Asia along which repeated island-crescents and the bands of islands are strung as upon no other coast of the globe, the thought is forced irresistibly upon one that a common cause must lie at the basis of this marginal festooning of the Asiatic continent."

Further he says:

"These examples and problems may suffice. They show that the most important facts in the largest numbers which it has up to the present been possible to discover respecting the position of tectonic lines, relate to Europe and the borderland of Eurasia. A binding together of the parts, and any sort of synthesis, would not have been possible at the time of the appearance of the second volume, for the reason that all interior parts of Asia, in which the connection of the crescents must be sought (Siberia and Mongolia), were almost completely unknown. The latest works of Russian explorers have for the first time furnished the possibility of such an attempt."

To review the more than five hundred pages of Suess's work, packed as it is with local data carefully digested and correlated with those of neighboring regions, would be to write a more or less extended treatise upon Asiatic geology. The book is, moreover, accessible to most readers of geological literature. It is sufficient to state that the same principles which were shown to be so important in determining the broad features of European topography and geology apply equally to the Asiatic continent. The evidence that deforming agencies responsible for tectonic structures and for surface features of the first order of magnitude have been operative throughout the entire region, have been supplied with only less fullness. The great importance of disjunctive processes, which have allowed the sections of the earth's crust to move up or down with reference to each other, thus dividing the country into plateaus or landsteps, is no less forcibly presented than was done in the earlier volumes.

With this first half of the third volume of *Das Antlitz der Erde* is printed a map upon which some of the larger lines of faulting have been indicated. The portion of this map which comes within the region here under consideration has been reproduced in figure 1. The course of the Ho-ang or Yellow river is indicated upon the map in its southern portion, and the great plain of China by the white area in the extreme

[illegible] GRAPHICAL VALUES CHARACTERISTIC OF THE [illegible]

[illegible]	Border of the step (Staffelrand)	Eastern Boundary
[illegible]	*Yunnan* crescent	East *Yunnan* fault
[illegible]	*Kwei* (Kui) crescent....	*Hukwang* fault
[illegible]	*Honan* crescent	*Honan* fault .
[illegible]	*Taihangshan* (Taihang) crescent.	*Taihangschan* Taihang fault .
[illegible]	*Khingan* crescent.......	*Khingan* fault [illegible]
[illegible]	[illegible] *Stanowoi* (Stanovoi) crescent	*Aldan* Range *
[illegible]	North *Stanowoi* (Stanovoi) crescent.	Without particular names......

[illegible] the mountainous region to the north and west [illegible] the more important of the tectonic lines.

[illegible] likely to meet the eye of the geologist are [illegible] v. Richtofen in the *Sitzungsberichte* of the Ber- [illegible]. The first of this series of three is devoted to the [illegible] represented in part upon the map which has been re- [illegible] from [illegible] what v. Richtofen has distinguished as [illegible] series of *Landstaffeln*, a word which has here been translated *landsteps*. v. Richtofen shows that along a line nearly parallel with the Pacific coast of Asia there runs a [illegible] of contiguous and more or less crescent shaped plateaus (*Landstaffeln*) all convex to the southeastward. v. Richtofen seems to regard it as significant that this series of landsteps extend across the continent so as closely to approximate to a great circle of the earth.

The author's views are so fully summarized in the concluding section, that it is thought best to reproduce them entire in translation. The many different spellings adopted by the different authors for Asiatic geographic names introduce the greatest confusion into the study. The translator

* There appears to be an error here inasmuch as the Aldan Range is in the same latitude as Khingan Range, the error being to give the western rather than the eastern limit to the land step. The eastern limit is a northern section of the *Stanowoi* (Stanovoi) Range.—[TRANSLATOR.]

LAND STEPS AND OF THE ENTIRE FAULT LINE.*

Extent of the step in the direction of the meridan		Length of the crescent (Bogen) †	Offset of each step to the eastward		Relation of m to n
In degrees of latitude approximately	In kilometers on meridian approximately (m)		In degrees of longitude approximately	In kilometers approximately ‡ (n)	
22⅔-25 N.	255	450	2½°	250	1 : 1
25-32½ N.	830	1200	4⅔°	550	1.5 : 1
32½-38 N.	600	750	3°	270	2.2 : 1
38 - 54 N.	1760	1900	8°	580	3 : 1
50 - 62 N.	1330	2000	18½°	1100	1.2 : 1
62 - 66 N.	440	2600	49°	2400	.18 : 1

has therefore used the German spelling of v. Richtofen, placing after each word in parenthesis the spelling of the Century Atlas. To render the geographic descriptions intelligible a map is necessary, and one of the excellent German maps from Andreés Handatlas, upon which the tectonic lines referred to and the great circle to which they approximate have been sketched in has been furnished from v. Richtofen's description. It should be used as a guide map in following v. Richtofen's descriptions which follow: The map of figure 1 is on a much smaller scale and includes the area covered by figure 2, mainly between the Yellow and Amur rivers.

RESULTS AND CONCLUSIONS.

A. MORPHOLOGICAL RELATIONS.

a. Along a line which begins somewhat south of the Tropic of Cancer in about 130° east longitude, and which may be followed to the Arctic circle in 190° east longitude, are arranged a series of contiguous crescent-shaped land-steps (*Landstaffel*) convex to the southeastward, which have the peculiarity in common that the section of the earth's crust immediately to the east always stands lower than the one to the west.

* All figures are only approximate values.

† The equatorial limb is here reckoned only from the junction with the meridional section which follows to the south.

‡ Reckoned as the average breadth.

c) The border of each step consists of two rectilinear or gently curved converging sections, (i. e.: an easterly meridional and a southerly equatorial section), which are joined with one another to form a crescent of larger or smaller radius of curvature. The more exact direction of the eastern limb is on the average S. by S. W.—N. by N. E. [illegible] in the northern steps more toward the N. E. The direction of the equatorial limb varies little from W. S. W.—E. N. E.

d) The equatorial portion of the border of each step crosses the meridional portion of the crescent next farther to the south. There [illegible] effected in the direction towards the pole an advance of the [illegible] eastward like that of the wings upon the stage of a theater. The equatorial section in the majority of instances stretches out [illegible] over the point of junction with the meridional. A concentration [illegible] is nowhere found.

e) The morphographical relations given under a, b, and c, above are [illegible] from the numerical values in the adjoining table: (See pp. 72-73.)

f) [illegible] a tangential great circle through the point of intersection of the meridian of 95° east with the equator and of the 66th parallel [illegible] to the westward of Behring straits (in Longitude 185° [illegible]) the eastward curves of the land-steps adhere to it with sufficient [illegible] to make it probable that the falling together of both lines is [illegible] significance.‡

g) The entire series of crescents forms a continental divide between [illegible] and inland east Asia, without regard to whether the former [illegible] as about the sea at *Ochotsk* (Okhotsk) and in the narrow [illegible] of coast of *Liau hsi* (Liao-si) between Pekin and Mukden, or whether it reaches a breadth of more than 1,000 kilometers, as in the [illegible] of Manchuria and China lying outside the inland region. The [illegible] of the divide is:

1. Purely morphographic; this is comprised in sections a. to e.

2. Hydrographic. The great streams of east Asia have their sources for the most part far to the west of this line, but first enter upon their quiet lower reaches where they cut through this line. This [illegible] of *Amur* and Yellow rivers, the basin of the latter stream at the point of crossing being restricted to little more than the stream channel; of the *Han kiang* (Han river), *Yang-sze-kiang* (Yang-tze river), *Yuen-kiang* (Yuan river), *Hsi kiang*, and *Song-ka* (Song-koi—Red River). Eastward from the line of breaking through, the broad land areas are coursed by navigable streams, which, to the south of

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* This appears to be an error as the great circle described in the foot note would pass far to the west of this point. [TRANSLATOR.]

‡ This great circle runs past the places *Ochotsk* (Okhotsk), ***Ayan, Tsitsilkhar*** (Tsitsikar), *Pau-ting-fu* (Pao-ting), *Hsiang-yang-fu* (Sing-yang), ***I-tschang-fu*** (I-chang), which lie at the foot of the individual steps **at distances** varying from 0—50 km. It penetrates then western *Kwang-si*, **120 km. east of** *Pese-ting* (Pose), and forms the medial line between the *Kwei* **(Kui) crescent** which projects somewhat towards the east and the *Yunnan* **(Yunnan) crescent** remaining to the west. It should be remarked that **this section of the crescent** lies in the continuation of another section of the crescent **belonging** to the same great circle, which forms the medial line of the **Pacific ranges of** North America, which are oriented essentially parallel to it.

a line that continues the *Tsin-ling-schan* (Tsin-ling range) line, form a densely crowded network, though northward of that line they are spaced with wider intervals. Westward from the series of crescents, navigation is interfered with or is difficult; only on the *Yang sze-kiang* (Yang-tze-river) there lies farther up in the Red Basin of the *Sz-tschwan* (Sze-chaun) still one other region of better navigation as a consequence of regionally less intensive and more intensive erosion.

3. Commercial geographic. Commerce is conducted in general freely and openly to the east of the series of crescents: except in south-eastern Manchuria where the mountains fix its limit. The land-steps, in spite of their generally small altitude, present a bar to commerce, which, on these land routes, as in the case of ocean routes, have only in a few cases been overcome. Maritime east Asia is hence closed off from the inland country. This is even in those places the case, where, as in *Schen-si* (Shen-si) and Mongolia, open lands again follow upon the other side with easy conditions of communication.

4. Climatic. Although all land in east Asia, or as far as *Ochotsk* (Okhotsk), is under the influence of monsoon climate, yet the dividing character along the line determined by the step borders is in some places recognizable and probably everywhere present. The separation is sharp in *Stanowoi* (Stanovoi). It is present in the *Seya* (Zeya) range and *Olekma* ranges and the *Khingan* as shown by the contrast of the park landscape and the deciduous features on the *Amur* with the Siberian conifers and the dry steppes of Mongolia. Only in one region west from *Nonni* and *Tung-liau-ho* (Tung-lia river) do the latter extend eastwards over the *Khingan*. For the stretches lying farther to the south it is sufficient to point out the contrast between the great plain which extends from Pekin to *Hwai* (Huai) on the one hand, and countries which lie on the other side of the land-steps—Mongolia, *Ordosland*, and *Schen-si* (Shen-si), on the other hand. In southern China the separating influence is veiled by the much stronger one that is exercised by increasingly high mountain ranges.

B. RELATIONS OF THE AREAS OF THE EARTH'S CRUST WHICH BORDER THE SECTIONS OF CRESCENTS TO ITS INTERNAL STRUCTURE.

a. The following are certain peculiarities of the internal structure of those areas in east Asia which come here under consideration:

1. Fundamental gneiss and gneiss granite in the basement are found in China only in *Schan-tung* (Shan-tung); the internal structure showing the constant strike direction of N. N.W.—S. S. E. Obrutschew determined it in the ancient gneiss to the eastward of *Baikal* as W. N. W.—E. S. E. In all other Archean rocks of continental east Asia, which lie to the eastward of the meridian 105° East and to the northward of the Tropic, the Sinian strike direction (average W. 30° S. to E. 30° N.) appears to predominate strongly and to control regionally the basement structure. Only one important exception is known; it is afforded by the relatively narrow but compactly constituted *Tsin-ling* zone in whose structure the *Kwen-lun* (Kuen-lun) strike direction (W. by N.—S. by E.) controls exclusively. This zone of intense folding must have

been indicated from the earliest times, since the ranges which are oriented in the Sinian direction approach one another at their northern and southern limits.

2. The ancient Paleozoic cover resting upon the eroded basement lies horizontal and apparently unbroken in the *Lena-Olenck* country; the Triassic occurring in higher latitudes, and the Upper Jurassic transgression stretching from here to the latitude of *Jakutsk* (Yakutsk), have the same position. The remaining portion of the entire region is divided into two portions by the *Tsin-ling* range and its imaginary eastern continuation. North of this line the sediment plateau has suffered no foldings, or at most very slight ones of the nature of bowings-up, described by Suess as back-folds (*Ruckfaltungen*) which are locally restricted. On the other hand it is broken into horizontal lying or gently inclined portions displaced in reference to one another; in part these have the form of irregular blocks and *Schollen*, as in *Schantung* (Shan-tung); in part they appear in long parallel strips, as in the north Chinese and Daurian ranges. The faults appear in part in the form of flexures. To the south of the *Tsin-ling* zone this plateau is divided first into crowded, farther away into broad, open folds, with abundant superimposition of middle and upper Paleozoic, as well as in places of old Mesozoic marine beds, in which the Sinian strike controls the character of the landscape.

b. The collective arrangement of the system of faults is independent of the internal structure. This is different in the different land-steps enclosed by the individual crescents—its fundamental lines may be grouped together as follows:

1 and 2. *Yunnan* (Yunnan) crescent and *Kwei* (Kui) crescent surround the horst-like massif of *Yunnan* (Yunnan) and *Kwei-tschou* (kui-chau). Much fractured (*Verkarsteter*) limestone predominates in it; but the mountain structure is not known. The meridional arrangement of individual form elements in eastern *Yunnan* (Yunnan) allows the presumption of the step-like sinking inward to the east. Farther to the north the *Hukwang* fault encloses as a part of the *Kwei* (Kui) crescent the eastern range of the *Ta-pa-schan* in the Sinian direction, which is here moderately folded to the southeast. It is probable that this folding continues in the horst of *Kwei-tschou* (Kui-chau).

3. In the step-province enclosed by the *Honan* crescent the main range of the *Tsin-ling* protrudes as a massive range, strongly folded, distinguished by southerly directed compression and over-turning, and controlled by the strike direction W. by N. W.—E. by S. E. It is accompanied in the north by similarly directed, partly low, partly very high, mountain ranges, which have not been subjected to folding since the Cambrian. Zonal sinkings can may be distinctly made out in the northerly inclined orographic blocks arranged along parallel faults. The *Honan* fault cuts off the entire complex upon the east.

4. The crescent of the *Tai-hang-schan* (Tai-hang mountains) borders a Carboniferous plateau which owes its origin to a relatively deep and very uniform depression of the district as a whole. The plateau

land is many times faulted in a meridional direction with slippings-down to the eastward; and slopes to the eastward in step-faults, but to the southward in a flexure.

5. Within the eastern Mongolian land-step is spread out veiled land from which certain mountain ranges jut up having predominate Sinian strike. From the few investigations at our disposal these ridges appear to be in structure not essentially different from the adjoining north Chinese and Daurian mountain regions to the south and north, which are separated by faults into gridiron-like parallel systems.

6 and 7. The *Sud-Stanowoi* (South Stanovoi) crescent surrounds a perfect ancient Paleozoic plateau, extending in the southwest to the high ridges, within which plateau folds and faults have been proven. The interior of the *Nord-Stanowoi* (North Stanovoi) crescent is geologically unknown. The north outlier of the *Verk-hoyanskii* range, concerning which excellent observations by Baron Toll are available, is too far removed to come here under consideration.

c. If we separate the individual crescents into their two components it is found that only in the meridional sections is the independence of internal structure* expressed. The faults of the *Aldan* range in the *Khingan* in the *Tai-hang-schan* (Tai-hang mountains), and the *Hukwang* fault cut across the dominating Sinian strike direction in the basal structure of the corresponding steps at angles of 120 to 140 degrees, while the *Honan* fault is parallel to the Sinian direction, but crosses the interior ridges of the steps connected with it at 90 degrees.

As regards the form of the eastern falling-in, the step-fault is proven in the *Tai-hang-schan* (Tai-hang mountains). The parallel grouping within the zone of falling-in makes this form probable in the *Khingan* and the *Aldan* ranges. It is doubtful in the *Tsin-ling-schan* (Tsin-ling mountains) and in the vicinity of the *Hukwang* fault, while on the eastern side of *Yunnan* (Yunnan) certain facts can be introduced favoring step-faults.

The aggregate amount of the depression is in all cases considerable. In most cases it is certainly not less than two kilometers (about 6,500 feet), probably it is throughout notably greater.

Respecting the manner in which the eastward lying crustal areas are affected by the falling inward, I do not venture here to say. It may be that in the latitudes in question, 1: the entire area stretching to the eastern margin of the continent has been depressed, or, 2: a *Graben* depression separates the high mountain land-steps from the other eastern ones; or, 3; the eastward lying orographic block is depressed only on one side against the fault line and ascends from it toward the east to the mountainous country.

d. The equatorial sections of the crescents follow the strike of the internal structure. They appear in consequence as deviations from the expression of the force which conditioned the great development of faults. The continental fault does not follow singly and continuously

* ***Inneren Bau.*** **This expression is evidently restricted in the author's mind to fold structures.**

the line of the great circle, but is decomposed into several more meridionally directed stretches, which, if one follows them from north to south, return to the average direction of the great circle by means of the equatorial stretches. Perhaps in this lies the basis for the fact that in northeast Siberia, where the great circle in question makes only a small angle with the parallels the equatorial stretches predominate in their extent; the meridional stretches on the other hand become proportionately shorter and describe a larger angle with the meridian than they do farther to the south. Surely in that case the marked western retreat from the south end of the *Hu[illegible]* fault forms part of an abnormal phenomenon and should be referred to some other cause.

In the equatorial sections, also, there have been tectonic processes connected with the building out of the land-steps. Just here occur the great flexures directed toward the plain of Pekin, the embayment of *Hwai-king-fu* (Huai-king), and the northwest coast of the inner Yellow sea. However the transitions from the high grounds of the land-steps to the deep land stretches at their foot are made generally very gradually and are brought about through frequently changing mountain land-scapes. They appear to be more abrupt on the south side of *Kwei-tschou* (Kui-chau) and *Yunnan* (Yunnan).

C. TYPE OF TECTONIC MOVEMENTS.

a. Crescent-shaped border swellings with land depressed in front easily give rise to the impression of a movement on a large scale of the upper parts of the earth's crust from the interior of the crescent outward and connected with uplifting of the front as well as with internal folds and overturns. Where this is found to be true there stand contrasted with the phenomena of tension—fracture and sinking in upon the back side—compression within the circumscribed area of the zone of overturning, and hence the eruptive rocks are usually connected with the former. I have elsewhere shown* that the *Tsin-ling-schan* (Tsin-ling mountains) owes its origin to such a movement directed from north to south, and, although the crescent form is in this case lacking, the phenomena mentioned are easily recognizable upon the north side.

b. Of the crescent forms which are here under consideration, not one of those which lie to the north of the *Tsin-ling-schan* (Tsin-ling mountains) appears to have the properties of a fold crescent. So far as observations are at hand they compel us to conclude that not compressive force from within outward but on the other hand tensional forces which operated from the outside lie at the basis of the fault development. Step depressions, which we can prove in many cases, [illegible] themselves [illegible] extension [illegible] space. But as always in the realm [illegible] where sections of a sediment plateau may lie at [illegible] the simple explanation is always, so [illegible] deeper lying portion along

* [illegible] p. 555

a fault plane which is steeply inclined outward, while a forcing up of the beds or an overturning has in no case been observed.

This holds for both components of the crescents. I think it may be concluded from this that the meridional faults point to a tendency of the eastern foreland to give way toward the east in the direction of the Pacific ocean; the equatorial faults to a similar yielding toward the south in the direction of the *Tsin-ling-schan* (Tsin-ling mountains) and its eastern continuation. To this doubled tension and the depression in consequence along two lines which meet under an obtuse angle may be ascribed the crescent-like sinking down in steps of the areas lying within the obtuse angle of the border of the orographic blocks which remain stationary.

In accord with this explanation are two other phenomena.

One is the recurrence of parallel faults of the same kind (same sense) in the rear land of the step-crescents. They appear to be more rare in the north and to increase in the breadth of the zone affected by them and in the number of faults as they approach the *Tsin-ling-schan* (Tsin-ling mountains). They point to regional control of extensions of the same kind dependent upon tension, which was relieved along certain lines, but which all fall in significance far behind the chain-like line of crescents within the great transcontinental line here considered. To the phenomenon of the parallel faults alone attention will here be directed; the question of the recurrence of crescent fractures of the same sense with the eastern foreland being left untouched.

The other phenomenon has to do with the occurrence of the eruptive rocks. They occur in those places where, in the case of the development of folds by overturning, they should be lacking, viz.: between the subordinate steps (*Theilstaffeln*) and in the outer margin of the crescent shaped marginal zones. In reference to the first mentioned occurrence it is sufficient to refer to what was said of the north Chinese and Daurian ranges; respecting the latter, the volcanic rocks may be thought of as on the Okhotskian slope of the *Aldan* range, on the east side of the *Khingan*, from Mergen to Mukden, on the outer margin of *Liau-hsi* (Liao-si), and in the embayment of Pekin. That they occur also upon the rear of the crescents, as on the southern border of Mongolia, and at *Witim* (Vitim), can only confirm a widely extended control of tensional forces of the same kind.

c. To the southward of the *Tsin-ling-schan* (Tsin-ling mountains) the observations do not suffice for the formation of a definitive verdict. For the meridional faults the explanation probably holds which was offered for the northern fractures of this kind. They cut through an old folded structure under an acute angle, and there is no indication present of a pushing forward of the upper limb over the lower or of a folding in perpendicular direction upon the line of depression; it can surely not be denied that eruptive rocks are not known along the latter. The equatorial lines on the south side of *Kwei-tschou* (Kui-chau) and *Yunnan* (Yunnan) appear none the less to be different from those of

[illegible] movements. Whether in them a pushing toward [illegible] first be shown after more exact investigation.

[illegible] TECTONIC MOVEMENTS.

[illegible] age of the fault structure meets [illegible] where the geological chronology [illegible] the absence of marine deposits of age younger [illegible] the ocean sediments end for the most part with [illegible] determinations the fresh water deposits [illegible] support.

[illegible] in his profound work upon the asymmetry [illegible] which compresses great results into small compass, [illegible] folds, so far as it concerns Asiatic soil, was [illegible] Cambrian time, the completion of its form, however [illegible] Tertiary time. This holds for the broader outline [illegible], but is not, however, immediately applicable [illegible][*]

AGE OF THE MISSOURI RIVER.

By WARREN UPHAM, St. Paul, Minn.

[illegible] sea covered the area of the Plains during the Cretaceous period, stretching from the Gulf of Mexico northward through the United States and far into Canada, perhaps [illegible] Arctic ocean, with its eastern shore crossing Iowa and [illegible] it is evident that the Missouri and Mississippi rivers cannot be more ancient than the Tertiary era.

Great rivers undoubtedly flowed into this Cretaceous sea from the east, but we can scarcely trace their courses or outline their basins. It seems most probable, however, that one of the chief river systems of that time coincided with the present series of the Great Lakes tributary to the St. Lawrence, but discharged its waters westward, opposite to the present direction. Another large river may have brought its [illegible] of detritus from the area of Hudson bay and the Nelson river, its flow being similarly the reverse of the present course.

In the region of the Ohio river many changes of drainage have taken place in connection with the continental glaciation, as made known by studies begun twenty-five years ago by

[*] Sitz. d. k. Akad. d. Wiss. zu Wein, Math.-Nat. Cl., vol. 107, p. 94, (1900).

[illegible] See the [illegible] paper of this series, AMER. GEOLOGIST, vol. xxxiv, pp. 25-39, July, 1904.

Carll in Pennsylvania and since continued and extended by Spencer, Foshay, Chamberlin, Leverett, Tight, and others.* The upper waters of the Ohio are now known to have flowed in preglacial times into the Lake Erie basin; but apparently the drainage thence passed westward, as before noted, being thus tributary to the Cretaceous inland sea, presumably by the way of lake Superior, and afterward to the Tertiary river which is now the Mississippi, reaching it probably by a route nearly coincident with the Illinois river.

The lower part of the Ohio river basin, with the tributary Cumberland and Tennessee basins, may have sent its waters directly to the western Cretaceous sea, flowing across the country traversed by the Missouri river below Kansas City; but with the inauguration of the Mississippi river, during the Tertiary era, that trunk stream must have received important branches from the lower parts of these two great basins. the Ohio and the Missouri, nearly as today. Even in the Cretaceous period, too, it is perhaps more probable that the lower Ohio and the lower Missouri from Kansas City eastward, with its continuation in the course of the Mississippi, both emptied into the Cretaceous ocean near the site of Cairo, Illinois, at the present mouth of the Ohio; for so far northward extended a great embayment of the Atlantic during the Cretaceous and Eocene periods.

With the epeirogenic uplifting of the Plains from the sea, near the end of Cretaceous time, and the contemporaneous folding and upheaval of many ranges of the Rocky mountains, there ensued very abundant estuarine, lacustrine, and fluvial deposition, of partly brackish, but mainly freshwater beds of very great extent and depth, often including layers of lignite, overlying the marine Cretaceous series. In the Dakotas and Montana and northward, on the country of the upper Missouri and the branches of the Saskatchewan, these beds belong almost wholly to the latest Cretaceous stages; but southward, in Wyoming, Nebraska, Colorado, and Kansas, they extend onward from the late Cretaceous to the Miocene and Pliocene periods. Their material has come chiefly from the erosion of

* The latest and most complete discussion of the complex history and development of the Ohio river system has been given by FRANK LEVERETT in *Monograph XLI, U. S. Geol. Survey*, "Glacial Formations and Drainage Features of the Erie and Ohio Basins," 1902, chapter iii, pages 82-219.

the mountain ranges on the west, and secondarily from erosion and redeposition of the very thick beds first so spread out on the western borders of the Plains, adjoining the mountains. Estuarine conditions are indicated here and there, though not generally, in the Laramie formations, terminating Cretaceous and Mesozoic time; but the greater part of the Laramie and all of the Tertiary formations are freshwater deposits.

Many geologists have ascribed these very extensive freshwater beds to sedimentation in vast lakes. Prof. W. M. Davis has shown, however, that the physical characteristics of these formations, as well as their fossils, indicate instead that rivers, meandering in variable courses, and in their seasons of flood spreading far and wide, were the agents of deposition, bringing the sediments from the ever progressing erosion of the mountains.*

The alternations of gravels, sands, and clays, with frequent cross-bedding and local unconformities, in the deposits that have been supposed to belong to the central parts of large lakes, are evidently more accordant with the explanation of these areas as flood-plains of rivers. Shallow playa lakes of moderate extent undoubtedly existed temporarily in many inclosed basins, and on some areas occasionally large and deep lakes may also for some time have received sediments from inflowing rivers and from shore erosion; but the view presented by Davis, that fluvial deposition accounts for the far greater part of these late Cretaceous and Tertiary beds, seems most acceptable.

Following the deposition of the extensive and thick Laramie strata on the Plains through which the Missouri river flows, a depth varying from 500 to 5,000 feet (increasing from east to west) of these and the underlying Cretaceous beds was eroded by rains, rills, brooks, and widely wandering rivers, reducing this region mostly to a peneplain. The vertical uplift above the sea level, and the concomitant and subsequent depth of denudation, wearing down the uplifted land until its surface was again mostly near that ultimate baselevel, are measured from occasional groups of mountains and hills

* *Proceedings, Am. Academy of Arts and Sciences*, vol. xxxv, pp. 345-373, March, 1900. AM. GEOLOGIST, vol. xxv, p. 313, May, 1900. See also an earlier important paper bearing on this question, by W. D. MATTHEW, *Am. Naturalist*, vol. xxxiii, pp. 403-408, May, 1899; AM. GEOLOGIST, vol. xxiv, pp. 250-251, Oct., 1899.

consisting partly or wholly of the nearly horizontal strata, spared from erosion while all the surrounding country was being baseleveled. Such are the Turtle mountain and the Crazy and Highwood mountains described in my last foregoing paper.

The Hand hills, in eastern Alberta, and the Cypress hills, in southwestern Assiniboia, are similar high remnants of the Cretaceous strata, rising 1,500 to 2,000 feet above the surrounding Plains; but they also show, above the Laramie and other Cretaceous formations, a capping of Miocene conglomerate, sandstone, and sandy clays, of fluvial deposition. It cannot be doubted, therefore, that Miocene deposits, somewhat like the Miocene and Pliocene formations in Wyoming and Nebraska and southward, once had a considerable development throughout the Canadian part of the Plains ; and it is also evident that, since so comparatively late a stage in the Tertiary era, a vast amount of denudation has taken place there. It thus seems very sure that likewise much of the denudation on the adjacent region of the Plains drained by the Missouri river belonged to the late part of Tertiary time. It progressed probably through nearly the whole of that long era, completing the baseleveling, so far as that was attained, near the end of the Pliocene period, the Plains through most or all of their extent being then worn down to only a slight elevation above the sea.*

Stream deposition had been very abundant, widely extended and deep, during the early part of the time since the original uplifting of the mountain ranges and plains drained by the Missouri river and its tributaries. During the latter part of that time, until the end of the Tertiary era, the Plains underwent great denudation and a general baseleveling, which apparently coincided, as to both beginning and end, with the Tertiary or Somerville cycle of partial baseleveling which Davis and Wood have studied in Pennsylvania and northern New Jersey and believe to have affected a large area of the other eastern states.†

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* *U. S Geol. Survey, Monograph XXV*, 1895, "The Glacial Lake Agassiz," pp. 81-107.

† *National Geographic Magazine*, vol. i, 1889, pp. 183-253; vol. ii, 1890, pp. 81-110. *Proceedings, Boston Society of Natural History*, vol. xxiv, 1889, pp. 365-423.

The termination of the cycle of abundant fluvial deposition and of slowly progressing erosion upon our great western Cretaceous area and the renewed epeirogenic uplift to undergo the erosion of the broad and flat Red river valley along its eastern margin in Minnesota, North Dakota, and Manitoba, were probably also contemporaneous with the great epeirogenic movement which in California, according to Mr. J. S. Diller, ended a long period of base-leveling that had extended through the whole of Cretaceous and Tertiary time, and raised a part of that base-leveled district at the beginning of the Quaternary era to form the lofty Sierra Nevada.* Again, a similar record of long-continued baseleveling, followed by uplift and a new cycle of rapid valley erosion, is found by Powell and Dutton in the plateaus and Grand Canyon of the Colorado river.†

Like the great changes of drainage which have formed the Colorado river, so I think the Missouri river also to have been made compositely, and to have taken its present course, since the Quaternary era began, with its general epeirogenic elevation of the greater part of North America to an altitude 3,000 to 5,000 feet higher than now, which led to snow and ice accumulation and the prolonged glaciation of the northern half of this continent, excepting Alaska. This opinion was first reached by Gen. G. K. Warren,‡ and has been more amply considered and stated by Prof. J. E. Todd.§ The continental ice-sheet turned aside the rivers of the northern part of the Plains, deflecting the Tertiary predecessor of the Missouri to the west and south from its preglacial course, which may have occupied a part of the valley of the James or Dakota river, nearly parallel with the Missouri of today, or which perhaps farther north passed eastward to the most southern bend of the Souris river, or to the Sheyenne and Red rivers. Pro-

* *U. S. Geol. Survey*, Eighth Annual Report, pp. 428-432. Compare also articles by Prof. Joseph LeConte, *Am. Jour. Sci.*, third series, vol. xix, pp. 176-190, March, 1880; vol. xxxii, pp. 167-181, Sept., 1886; vol. xxxviii, pp. 257-263, Oct., 1889.

† Exploration of the Colorado River of the West, 1875. Geology of the eastern portion of the Uinta Mountains, 1876. *U. S. Geol. Survey, Monograph II*, Tertiary History of the Grand Cañon District, 1882. *Amer. Jour. Sci.*, third series, vol. xxxii, pp. 170, 171, Sept., 1886.

‡ *Annual Report of the Chief of Engineers*, U. S. Army, for 1868, pp. 307-314.

§ *Proc. A. A. A. S.*, vol. xxxiii, 1884, pp. 381-393; *U. S. Geol. Surv.*, Bulletin No. 144, 1896, p. 57. Compare also a paper by Prof. E. W. Claypole, "The Story of the Mississippi-Missouri," Am. Geologist, vol. iii, pp. 361-377, June, 1889; and a paper by Prof. G. C. Broadhead, "The Missouri River," Amer. Geologist, vol. iv, pp. 148-155, Sept., 1889.

fessor Todd finds also in the topography of that region evidence that in preglacial time the great tributaries coming from the west to join this part of the Missouri, namely, the Cannon Ball river, the Grand and Moreau rivers, then united, the Cheyenne, and the White river, flowed east to the James valley; and he is inclined to believe that from that valley the great stream formed by these affluents passed northeast to the Red river of the North and Hudson bay.

In this view I very heartily concur, as a good confirmation of it seems to me to be afforded by the contour of the Coteau des Prairies, lying between the Minnesota river valley and that of the James river. Rising very gradually, without definite boundaries southward in Iowa and the southwest corner of Minnesota, this massive highland runs north-northwest to a high termination, called the Head of the Coteau, like a promontory, between the James valley on the west and the continuous and broad Minnesota and Red river valleys on the east. I attribute this form to preglacial stream erosion, when two great rivers here united, flowing northward. The western stream may have been the ancient Missouri river, while the eastern probably drained the upper part of the Mississippi basin, deriving its most eastern and southern waters from parts of Wisconsin and the northeast corner of Iowa. According to Hershey, the preglacial divide crossed the present course of the Mississippi somewhere between LaCrosse and Dubuque.*

The erosion of the present valley of the Missouri river, from where it leaves the mountains to the mouths of the Niobrara and James rivers, ranging below the Great Falls from one to ten miles in width and from 300 to 600 feet in depth cut into the general surface of the plains, may be ascribed wholly or chiefly to the work of this great stream since the culmination or Kansan stage of the Ice age, probably 50,000 years or longer ago, when the drift thinly overspreading the country along the course of the river was deposited. Only on the east side of the river at various places in South Dakota is its valley touched by the border of the much later drift sheet spread during the moraine-forming Wisconsin stage, near the end of the Glacial period.

* "The Physiographic Development of the Upper Mississippi Valley," AM. GEOLOGIST, vol. xx, pp. 246-268, Oct., 1897.

So long a time have the Missouri and its tributaries been at work, with a good rate of descent, eroding the mostly soft Cretaceous strata, in an unceasing task estimated by the present writer as seven to ten times longer than the postglacial period since the ice-sheet melted away from much of the area of South and North Dakota, from Minnesota, Wisconsin, and the moraine-inclosed part of all the northern states and of Canada. But through a still longer time, ever since the early Quaternary uplifting of the Plains from their low baseleveling, that is, probably 150,000 years, more or less, have most of the large streams outside the glaciated area been cutting down their valleys.

What some of these streams, with their branches and adjoining springs, have accomplished in sculpturing picturesque and almost indescribable chasms, gorges, and ravines, is the scenic and geologic wonder of the Plains, the widely famed "Bad Lands" (*Mauvaises Terres*), so named by the early French fur traders and trappers, because of the difficulties of traveling through or across these wildly and fantastically eroded tracts. This frequent phase of valley erosion under a somewhat arid climate is perhaps best displayed along the Little Missouri river, in the west part of North Dakota. It is well seen on a width of several miles in the vicinity of Medora, where the Northern Pacific railway crosses this valley, and also along all the course of this stream far to the south and north of the railway, to its union with the Missouri river. The weird effects of the forms of erosion are further enhanced here by the bright red color of some of the beds, and in numerous places by jet black lignite seams.

Twenty years ago Theodore Roosevelt had a cattle ranch in this valley a few miles south of Medora, and ranged in his hunting excursions over all parts of these Bad Lands and the adjoining plains. His description of the valley sculpture, in "Hunting Trips of a Ranchman," may well close this paper, as follows:

Our route lay through the heart of the Bad Lands, but of course the country was not equally rough in all parts. There were tracts of varying size, each covered with a tangled mass of chains and peaks, the buttes in places reaching a height that would in the East entitle them to be called mountains. Every such tract was riven in all directions by deep chasms and narrow ravines, whose sides sometimes rolled

off in gentle slopes, but far more often rose as sheer cliffs, with narrow ledges along their fronts. A sparse growth of grass covered certain portions of these lands, and on some of the steep hillsides, or in the canyons, were scanty groves of coniferous evergreens, so stunted by the thin soil and bleak weather that many of them were bushes rather than trees. Most of the peaks and ridges, and many of the valleys, were entirely bare of vegetation, and these had been cut by wind and water into the strangest and most fantastic shapes. Indeed it is difficult, in looking at such formations, to get rid of the feeling that their curiously twisted and contorted forms are due to some vast volcanic upheavals or other subterranean forces; yet they are merely caused by the action of the various weathering forces of the dry climate on the different strata of sandstones, clays, and marls. Isolated columns shoot up into the air, bearing on their summits flat rocks like tables; square buttes tower high above surrounding depressions which are so cut up by twisting gullies and low ridges as to be almost impassable; shelving masses of sandstone jut out over the sides of the cliffs; some of the ridges, with perfectly perpendicular sides, are so worn away that they stand up like gigantic knife blades; and gulches, wash-outs, and canyons dig out the sides of each butte, while between them are thrust out long spurs, with sharp ragged tops.

VARIATION IN THICKNESS OF THE SUBDIVISIONS OF THE ORDOVICIAN OF INDIANA.

With notes on the range of certain fossils.

By Aug. F. Foerste, Dayton, O.

PLATE V.

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[illegible] VARIATIONS IN THICKNESS OF ORDOVICIAN STRATA IN INDIANA.

1. The Subdivisions of the Ordovician of Ohio and Indiana.

The Ordovician of Indiana is merely the western extension of the Ordovician of Ohio. It presents the same divisions and subdivisions, contains the same fauna, and was deposited under closely similar conditions.

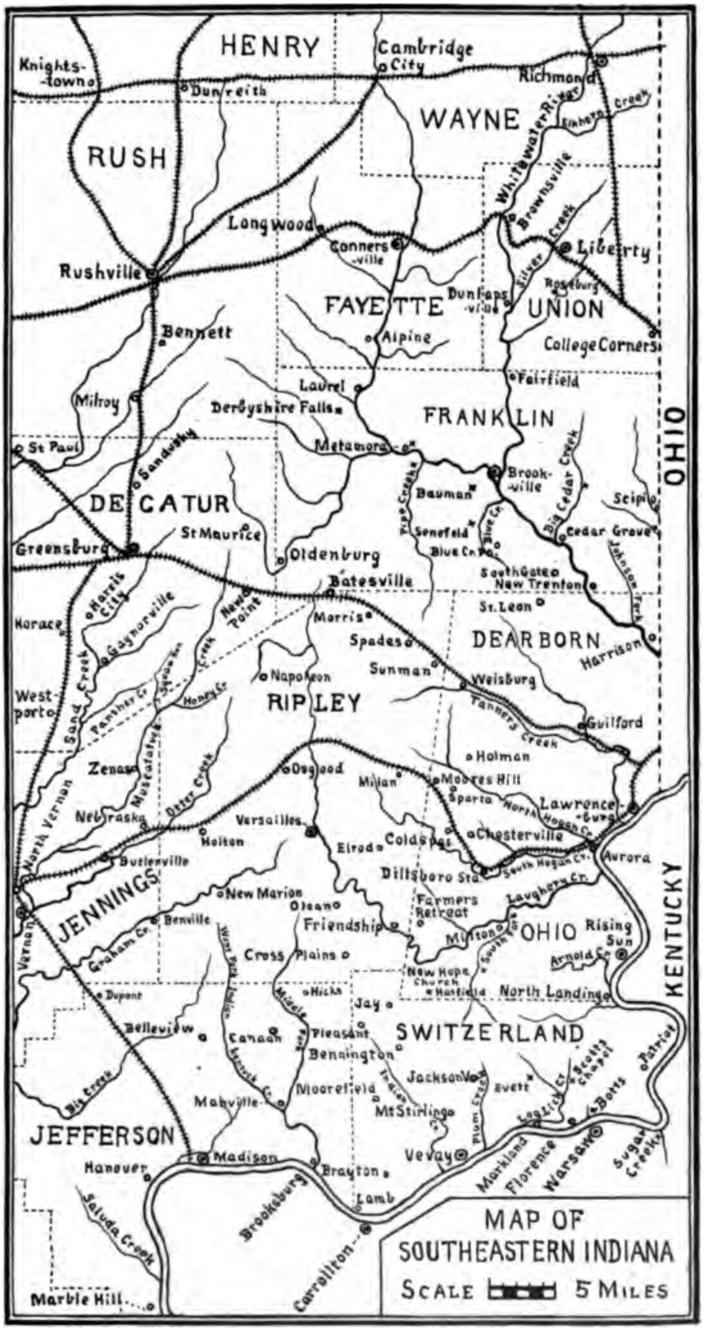
The following subdivisions were proposed by Mr. J. M. Nickles:*

Cincinnati	Richmond	Madison, Saluda	or Upper Richmond
		Whitewater, Liberty	or Middle Richmond
		Waynesville	or Lower Richmond
	Lorraine	Warren	
		Mount Auburn	
		Corryville	
		Bellevue	
		Fairmount	
		Mount Hope	
	Utica	Upper Utica	
		Middle Utica	
		Lower Utica	
Trenton	Probably Lower Trenton	Point Pleasant	

2. Diminution in Thickness of Utica, Lorraine, and Richmond southward.

All of the major divisions and most of the subdivisions diminish in thickness, from the more northern exposures in Ohio and Indiana, southward. In the case of the Utica, this diminution in thickness cannot be established within the areas exposed in Ohio and Indiana; however, the entire absence of the Utica in south-central Tennessee, in the area included between Columbia, Centreville, and Franklin, suggests that this

*AMERICAN GEOLOGIST, Oct., 1903.


HENRY
Knights-
-town
Dunreith
Cambridge
City
Richmond
WAYNE
Elkhorn Creek
Whitewater River
RUSH
Brownsville
Silver Creek
Longwood
Conners
-ville
Liberty
Rushville
Roseburg
Dunlaps
-ville
FAYETTE
UNION
Bennett
Alpine
College Corners
Fairfield
Laurel
Milroy
Derbyshire Falls
FRANKLIN
OHIO
St Paul
Metamora
Sandusky
Brook-
-ville
Big Cedar Creek
Bauman
Scipio
DECATUR
Pipe Creek
Blue Cr.
Senefeld
Cedar Grove
Johnson Fork
Blue Cr.
St Maurice
Greensburg
Oldenburg
SouthGate
New Trenton
Batesville
Harris
City
New
Point
St. Leon
Gaynorville
Morris
Horace
Spades
DEARBORN
Harrison
Sunman
Napoleon
Weisburg
West-
port
Sand Creek
Panther Cr
Honey Cr
RIPLEY
Tanners Creek
Guilford
Holman
Zenas
Muscatatuck
Otter Creek
Osgood
Milan
Moores Hill
Sparta
North Hogan Cr.
Lawrence
-burg
Nebraska
Versailles
Holton
Elrod
Coldsprings
Chesterville
North Vernon
Butlerville
Dillsboro Sta
South Hogan Cr.
Aurora
JENNINGS
New Marion
Laughery Cr.
Oleano
Farmers
Retreat
Benville
Friendship
Milton
OHIO
Rising
Sun
Graham Cr.
Cross Plains
Arnold Cr.
KENTUCKY
Vernon
New Hope
Church
Dupont
Hicks
Jay
North Landing
Belleview
Canaan
Pleasant
SWITZERLAND
Patriot
Bennington
Jackson
Evett
Scotts
Chapel
Big Creek
Moorefield
Mt Sterling
Plum Creek
Boots
Manville
Log Lick Cr.
JEFFERSON
Madison
Vevay
Markland
Florence
Warsaw
Sugar
Creek
Hanover
Brayton
Brooksburg
Lamb
Saluda Creek
Carrollton
Marble Hill
MAP OF
SOUTHEASTERN INDIANA
SCALE 5 MILES

diminution in thickness begins much farther north than Tennessee. According to Hayes and Ulrich*, the Utica is absent in the Richmond and London quadrangles on the eastern side of central Kentucky. Recently *Dalmanella multisecta* has been found nine miles north of Richmond, at Clays Ferry, in beds overlying strata referred to the top of the Trenton.

The Lorraine diminishes in thickness from 290 feet in the neighborhood of Cincinnati to 260 feet near Madison, Indiana. In south-central Tennessee, its thickness does not exceed 100 feet. Along the Tennessee river; at Clifton, a section, three and a half feet thick, may belong to the top of the Lorraine. It contains *Dinorthis retrorsa,* a species formerly believed to be restricted to the Warren bed, but this fossil has been found recently in Indiana also in the upper half of the Waynesville bed. Elsewhere in the Tennessee river valley of western Tennessee the Lorraine certainly is absent.

The Richmond diminishes in thickness from 300 feet in the southern part of Franklin county, Indiana, to 115 feet at Marble Hill, 60 miles southwest. In central Kentucky, much thinner sections are known. 'In southern Tennessee its thickness does not exceed 40 feet and averages about 20 feet.

3. *Diminution in Thickness of the Subdivisions of the Lorraine.*

The diminution in thickness of the Lorraine is accompanied, of course, by a diminution in thickness of certain of its various subdivisions.

No decrease in thickness is noted in case of the Bellevue and Warren beds within the limits of Indiana. The Bellevue bed is the chief *Platystrophia lynx* horizon of southern Indiana. At Cincinnati, where *Platystrophia lynx* is rare at this horizon, the thickness of the Bellevue bed is about 20 feet. Near Madison, in Indiana, its thickness varies from 20 to 24 feet. Southward, in Kentucky, the lower *Platystrophia lynx* or Bellevue bed forms one of the most constant horizons. The Warren bed has a thickness of 61 feet at Lebanon, in Ohio. At Madison, in Indiana, the thickness of the Warren bed certainly equals and probably exceeds this amount; the distance from the top of the Mount Auburn layers containing *Platystrophia*

* Folio 95, Columbia, Tenn., 1903.

lynx and **Coeloclema oweni* to the top of the Lorraine is 77 feet, but the lower part of this interval does not contain diagnostic fossils.

At Cincinnati, the Mount Hope-Fairmount section has a total thickness of about 130 feet. In southern Indiana, between Vevay and Brooksburg, this thickness averages between 90 and 95 feet. The occurrence of *Strophomena planiconvexa, Hebertella sinuata, Plectorthis plicatella,* and of the small Mount Hope form of *Platystrophia,* species first seen at the base of the Fairmont bed in Ohio, near the base of the Lorraine section in southern Indiana suggests that the considerable diminution of the Mount Hope-Fairmount section southward is due chiefly to the thinning of the Mount Hope bed.

At Cincinnati, the thickness of the Corryville bed is estimated at about 60 feet. At Madison, in Indiana, the base of the Mount Auburn layers containing *Platystrophia lynx* and *Coeloclema oweni* is 80 feet below the top of the Lorraine. The top of the Bellevue bed is between 130 and 134 feet below the top of the Lorraine. *Bythopora gracilis* and *Callopora ramosa* characterize the section up to 90 feet below the top of the Lorraine. The strata intervening between this level and the base of the upper *Platystrophia lynx* layers, known to be of Mount Auburn age, consist of nodular limestone and clay of unknown age. The thickness of the Corryville bed at Madison, therefore, can not exceed 54 feet, and possibly may not exceed 44 feet. At Lebanon, the thickness of the Mount Auburn bed is estimated by Mr. J. M. Nickles at about 20 feet. At Madison, only three feet can be definitely assigned to this bed, although the underlying, doubtful section, 10 feet thick, also may belong to this bed.

At Fredericktown, Kentucky, seventy miles south of Madison, the top of the great *Platystrophia lynx* bed, presumably of Bellevue age, is about 90 feet below the top of the Lorraine. *Strophomena planiconvexa* occurs 107 feet below the top of the *Platystrophia lynx* bed. This indicates the continued thin-

*All Bryozoans mentioned in this paper were identified by Mr. R. S. Bassler. These identifications in addition to many others form the basis of the stratigraphical work here described. The writer desires to express his great obligations for the favors received. Although much more abundant collections of fossils are necessary to determine the exact limits of the various subdivisions in Indiana, the present paper is offered as a contribution preliminary to such more detailed study.

ning southward of the upper beds of the Lorraine, but suggests very little change in the thickness of the Bellevue-Fairmount section between Madison and Fredericktown. In south-central Tennessee, the Lorraine section, 100 feet thick, includes the Fairmount, Bellevue, and Corryville beds; with *Platystrophia lynx* in the uppermost beds.

4. Diminution in Thickness of the Subdivisions of the Richmond.

While there is no doubt of the considerable diminution in thickness of the Richmond group as a whole, from the more northern outcrops in Ohio and Indiana southward, the relative diminution of its different subdivisions can not be determined definitely until their characteristic faunas are better known. However, in the mean time, a number of very suggestive observations, connected with the interval between the base of the *Hebertella insculpta* layer and the base of the Waynesville bed, also with the interval between the base of the *H. insculpta* layer and the base of the beds at present referred to the Madison, will prove of interest, especially in view of the fact that the base of the *Herbertella insculpta* layer has been proposed as the base of the Liberty division of the Middle Richmond.

a. Intervals between Hebertella insculpta layer, base of Waynesville and top of Whitewater beds north of Madison.

Comparatively little variation is noticed in the vertical dimensions of the interval between the base of the *Hebertella insculpta* layer and the base of the Waynesville bed between Union county, Indiana, and Madison. This interval amounts to about 83 feet at the localities west of the home of William Bauman on McCarthy creek southwest of Brookville; about a third of a mile above the mouth of Pipe creek; southeast of Cedar Grove on the road to South Gate; and north of Hogan creek on the road from Moores Hill to Holman. Along Silver creek in Union county the interval is probably equally great, since the exposures of the Waynesville bed opposite the home of Robert Martin equal 64 feet without exposing either the *Hebertella insculpta* zone or the base of the Waynesville bed. Southwest of Friendship on the road crossing the southeastern corner of section 13, also two miles southeast of Belleview on a road crossing Indiankentuck river, this interval is 70 feet. Southeast of Belleview, the thickness of the Richmond is 166

feet and the interval between the base of the *Hebertella insculpta* layer and the Clinton is 96 feet. Along the railroad at Madison, the Locke level measurements for the thickness of the Richmond are 170 feet, and the interval between the base of the *Hebertella insculpta* layer and the Clinton is 85 feet—both along the Canaan road two miles northeast of Madison, and along the Hanging Rock road at the northern edge of the city. Making full allowance for errors due to Locke level readings and to dip, a local increase rather than a diminution of the interval between the base of the *H. insculpta* layer and the base of the Waynesville bed is suggested. South of Madison, *Hebertella insculpta* is unknown.

The interval between the base of the *Hebertella insculpta* layer and the top of the Whitewater or the base of the Madison bed, on the contrary, diminishes rapidly southward. Half a mile southwest of Cedar Grove, on the road to South Gate, this interval is 140 feet. *Dinorthis subquadrata* has a range extending from 10 feet above the base of the *Hebertella insculpta* layer to 150 feet above the same. The exposure was divided into vertical sections of 10 feet, and in each of these *Dinorthis subquadrata* was found. The rubble limestone overlying this *Dinorthis* section is referred to the Madison bed. At Versailles, the interval between the base of the *Hebertella insculpta* layer and the base of the Madison bed layer is 61 feet. The base of the lowest massive *Tetradium* layer is taken as the base of the Madison, although *Columnaria alveolata* is found occasionally about a foot beneath this Tetradium layer. Two miles southeast of Belleview, *Hebertella insculpta* occurs 44 feet below a *Columnaria alveolata* layer. At Madison, along the Hanging Rock road, a few poor specimens of *Hebertella insculpta* were found loose about 31 feet below the lowest *Columnaria alveolata* bed which here forms the base of the Madison. This is probably the true horizon for *Hebertella insculpta*, since the lowest specimens of *Dinorthis subquadrata* at this locality occur about 28 feet below the lowest Columnaria layer, and since in that case the interval between the *Hebertella insculpta* layer and the Clinton would be 85 feet, an interval known to occur along the Canaan road two miles northeast of Madison.

South of Madison, *Hebertella insculpta* is unknown. Certain facts, however, suggest that some opinions may be formed as to the variation in thickness of the southern extension of the intervals between the base of the *Hebertella insculpta* layer, the base of the Waynesville and the base of the Madison bed, notwithstanding the absence of *Hebertella insculpta.* These facts are as follows:

b. Thickness of Hebertella insculpta layer.

In Franklin county and at St. Leon in the northern part of Dearborn county the *Hebertella insculpta* layer has a thickness of seven feet. Northeast of Moores Hill on Hogan creek, also two miles east of Cross Plains, it is five feet thick. South of Cross Plains it diminishes rapidly in thickness. Its thickness is only 1.5 feet three miles southeast of Cross Plains in the northwestern corner of section three, and at most points in the northeastern part of Jefferson county. Farther south, careful search often is necessary to secure specimens enough to make the identification of the *Hebertella insculpta* horizon certain.

c. Interval between Hebertella insculpta layer and base of Dinorthis subquadrata zone.

Dinorthis subquadrata entered the field later than *H. insculpta.* The base of the *D. subquadrata* zone usually is separated from the top of the *H. insculpta layer* by a short interval. At the north this interval apparently is greater than at the south. Thus at St. Leon, the lowest specimens of *D. subquadrata* occur about eight feet above the *H. insculpta* layer. Farther south the interval is five feet; for instance, in section 3, three miles southeast of Cross Plains, on the Poplar Ridge road three and a half miles south of Cross Plains, in the southwestern corner of section 19 six miles southwest of Cross Plains, two miles northwest of Canaan on a branch of Indiankentuck, and two miles southeast of Belleview on a road crossing Indiankentuck. Two miles east of Cross Plains the interval is 3.5 feet. Two miles northeast of Madison on the road to Canaan the interval is only two feet; this appears to be the interval also at Madison.

d. The Vertical Range of Dinorthis subquadrata north of Madison.

Half a mile southwest of Cedar Grove, on the road to South Gate, *Dinorthis subquadrata* has a vertical range of 140

feet. In the southern part of Ripley and Dearborn counties no sections are known in which the range of this fossil equals 40 feet. At Versailles, its range is 20 feet. Two miles east of Cross Plains, it is 15.5 feet; a single good specimen of *Calopoecia cribiformis* was found in the upper third of the *D subquadrata* zone. Two miles northwest of Canaan the range of *Dinorthis subquadrata* is 26 feet. At Madison its range is about 10 feet.

From these data it may be seen that the vertical range of *Dinorthis subquadrata* diminishes rapidly southward, also that the distance of the lowest specimens of *Dinorthis subquadrata* from the *Hebertella insculpta* layers decreases southward in such a manner that at the southern exposures the lowest specimens of *Dinorthis subquadrata* evidently are but a slight distance above the *Hebertella insculpta* horizon.

e. The Vertical Range of Dinorthis subquadrata south of Madison.

At Madison the base of the *Dinorthis subquadrata* horizon is 82 feet below the Clinton, the vertical range of the fossil being about 10 feet. At the Pinckney Swan locality, on Saluda creek, it occurs 75 feet below the Clinton and 65 feet above the base of the Waynesville bed. At the mouth of Bull creek, it occurs 63 feet below the Clinton, and ranges from this point upward for several feet. This diminution of the interval between the base of the *D. subquadrata* bed and the base of the Clinton is due apparently chiefly to a decrease of the interval between the base of the *Dinorthis subquadrata* horizon and the base of the beds referred to the Madison. It accords very well with the decrease southward of the interval between the base of the *Hebertella insculpta* layer and the base of the Madison, shown by the exposures between Franklin county and Madison.

Should the base of the *Hebertella insculpta* layer turn out to be a reliable marker of the base of the Middle Richmond, the preceding observations would indicate a very rapid diminution in thickness of the Middle Richmond from Franklin county as far as the mouth of Bull creek. The *Waynesville* bed on the contrary would not show any important variation in thickness between Franklin county and Madison, although south of Madison a rapid decrease in thickness would be indicated.

f. The Dalmanella jugosa zone of the Waynesville bed.

Quite different conclusions might be drawn from a study of the *Dalmanella* zone, at the base of the Richmond, alone. On the north side of Hogan creek on the road from Moores Hill to Holman, *Dalmanella jugosa* is common from the base of the Waynesville bed up to 65 feet above; it occurs in smaller numbers as far as the base of the *Hebertella insculpta* horizon, at an elevation of 84 feet. South of Friendship along the road crossing the southeastern corner of section 13, *Dalmanella jugosa* is abundant up to 40 feet, the base of the *H. insculpta* horizon being at 70 feet. Two miles southeast of Belleview along a road crossing Indiankentuck river, *Dalmanella jugosa* is common up to 30 feet, the base of the *H. insculpta* layer being at 70 feet. South of Madison, the vertical range within which *D. jugosa* is abundant diminishes rapidly. At the Pinckney Swan locality on Saluda creek it is abundant only within a few feet of the base of the Waynesville bed. This rapid diminution in the vertical range of *Dalmanella jugosa* between Moores Hill and Marble Hill at first thought suggested an equally rapid decrease in the thickness of the Waynesville bed southward. However, the data recorded in connection with the vertical position and range of *Hebertella insculpta* and *Dinorthis subquadrata* do not bear out this suggestion.

*g. The Madison, Saluda, or Upper Richmond bed.**

At Richmond the top of the characteristic Middle Richmond brachiopod fauna occurs 57 feet below the Clinton. Southwest of Laurel, at the Derbyshire falls, the base of the Tetradium bed is about 71 feet below. At Versailles, the interval is 60 feet. Two miles southeast of Belleview and six miles north of Madison, *Columnaria alveolata* occurs 52 feet below the Clinton. At Madison, and at Hanover, the interval is 54 feet. While the coral bed has not been located along Saluda creek or at Marble Hill, the corresponding interval is believed to equal or exceed 50 feet. Farther southward, in Kentucky, there is a distinct diminution in the thickness of the section referred to the Madison.

**Twenty-first Annual Report*, Indiana Geological Survey, p. 220. AMERICAN GEOLOGIST, June, 1903, plates XXI, XXII.

II. THE VERTICAL RANGE OF CERTAIN ORDOVICIAN BRACHIOPODA.

5. *Dalmanella emacerata. D. multisecta. D. meeki. D. jugosa.*

The lowest layers of the Trenton exposure along the Ohio river opposite Warsaw contain a large species of *Dalmanella*, usually 21, and occasionally 26 mm. wide. Compared with *Dalmanella emacerata*, its radiating striae are coarser and more distant; and the pedicle valve is more convex. Fifty feet above the river, west of the home of Louis Botts, the top of the Trenton contains *Eridotrypa briareus*, *Eridotrypa mutabilis*, and *Prasopora simulatrix*. In the central part of Kentucky this species of *Dalmanella* often is fairly common in the lower part of the Trenton. Typical specimens of *Dalmanella emacerata* occur in the Lower and Middle Utica at Cincinnati. The original shells must have been very thin; owing to pressure they have almost invariably been crushed flat. At Vevay, they are found in the Middle Utica, between 90 and 100 feet below the top of the Utica. The most abundant brachiopod of the Utica is *Dalmanella multisecta*. It ranges practically throughout the entire formation. In southern Indiana it is especially abundant in the upper part of the Utica, this fossil and *Dekayella ulrichi* extending to the very top.

In southern Indiana, the top of the Utica frequently is overlaid by a bryozoan layer varying from 2 to 4 feet in thickness, and consisting chiefly of numerous fragments of *Callopora dalei* and *C. subplana*. *Constellaria constellata-prominens*, *Dekayia aspera*, *Heterotrypa frondosa*, and *Perenopora vera* usually are present, but are much less abundant. At Vevay this layer contains also *Amplexopora septosa*, *Homotrypa cincinnatiensis*, and *Phylloporina variolata*. In Indiana, *Dalmanella multisecta* is practically absent in the Lorraine, being known at this horizon only at one locality, Guilford, and there only in the lowest beds.

Dalmanella meeki is common in the Fairmount bed at Hamilton, Ohio. It is common at the same horizon at New Trenton, in Indiana. It is found in small numbers half a mile east of Dillsboro station, near the base of the Fairmount, and also west of Dillsboro station, near the upper *Strophomena planoconvexa* horizon. Southwest of this locality it appears

to be very rare. The species is probably represented by Fig. 1d, of Plate 8, Ohio Pal., Vol. I, 1873.

In the Corryville bed along the eastern bank of the Whitewater at Brookville is found in considerable numbers a form of *Dalmanella* closely resembling the species which is so abundant in the lower part of the Waynesville bed, provisionally called *D. jugosa.* It is associated here with *Bythopora gracilis, Callopora ramosa, Heterotrypa inflecta, Homotrypa obliqua,* and *Leptotrypa clavacoidea.* At New Trenton it occurs in much smaller numbers in the Corryville bed, associated with the same bryozoans; it is found occasionally also in the Mount Auburn bed, associated with *Platystrophia lynx, Coeloclema oweni,* and undescribed Mount Auburn forms of *Eridotrypa* and *Dekayia;* it is fairly abundant at the base of the Warren bed, associated with *Homotrypa pulchra* and *Coeloclema oweni,* species occurring also in the Mount Auburn bed, *Coeloclema oweni* being usually diagnostic of the Mount Auburn.

In various parts of Franklin county, *Dalmanella* is very common in the upper part of the Warren bed: Southeast of Fairfield on the L. J. Logan farm it is common both below and above the *Dinorthis retrorsa* horizon. Along Templeton creek, a third of a mile east of the Brookville pike, it is abundant. At the Bauman locality southwest of Brookville it occurs in the upper part of the Warren bed. About a third of a mile above the mouth of Pipe creek, where the hill land reaches the creek, *Dalmanella* occurs for at least 10 feet both above and below the *Dinorthis retrorsa* horizon, the latter being 35 feet below the top of the Warren bed. The Warren bed form of *Dalmanella* closely resembles the species which characterizes the *Dalmanella* zone of the Waynesville bed.

There is no doubt that the form characterizing the *Dalmanella* zone of the Waynesville bed was the form for which the name *Dalmanella jugosa* was originally intended since this is the only form in the upper beds of the Cincinnati Group which can be said to be abundant. Its width often is seven-eighths of an inch, occasionally one inch. In local collections a small variety, slightly exceeding one-half inch in width, is often labelled *Dalmanella jugosa;* both valves are more convex than in the larger specimens; this variety occurs in the

Waynesville bed, but it can not be said to be common. Specimens of this size are found also at the top of the Middle Richmond at Dayton, Ohio, and at the top of the Madison bed northeast of Westport, Indiana, but are rare.

6. *Strophomena hallie, Str. planiconvexa, Str. planumbona, Str. neglecta, Str. vetusta. Str. nutans, Str. sulcata.*

Strophomena hallie is cited from the Lower and Middle Utica. At Vevay it occurs in the Middle Utica, between 100 and 120 feet below the base of the Lorraine, associated with *Amplexopora petasiformis*, also the variety *welchi*, *Aspidopora newberryi*, *Aspidopora eccentrica*, *Batostoma implicatum*, *Ceramoporella granulosa-milfordensis*, *Hemiphragma whitfieldi*, and *Stigmatella clavis*. Between 120 and 128 feet below the base of the Lorraine the section contains *Monotrypa subglobosa* and *Stigmatella nana*. A number of Lower Utica forms evidently range higher than hitherto suspected. At the junction of Mud Lick and South Fork, half a mile south of Milton. *Strophomena hallie* occurs at the base of the Upper Utica, 85 feet below the base of the Lorraine, associated with *Batostoma jamesi*, *Callopora nodulosa*, *Coeloclema alternatum*, *Dekayella ulrichi*, and other fossils of general range. North of Rogers Gap, in Kentucky, *Str. hallie* occurs in the lower part of the Utica, associated with *Dalmanella multisecta* and *D. emacerata*.

Strophomena planiconvexa, in southern Indiana, occurs quite constantly, although in small numbers, near the base of the Lorraine, at the top of the bryozoan layer or just above. At Vevay it ranges from three to eleven feet above the base; at Brooksburg it is eight feet above.

Four miles north of Vevay, on the Plum creek road about two miles south of Jacksonville, this species recurs 52 feet above the lower *Strophomena planiconvexa* horizon, and about 33 feet below the lower *Platystrophia lynx* or Bellevue bed. Three miles east of this locality, in the southwest corner of section 14, opposite the home of J. W. Evett, a large typical gerontic lower Lorraine specimen of *Platystrophia lynx* occurred in the same slab with *Strophomena planiconvexa* at this upper horizon. The upper horizon is exposed also along the upper part of the road ascending the hill east of Scott chapel, three miles north of Florence, along the eastern

branch of Lock Lick creek. Half a mile northwest of Dillsboro station, at the crossing of the road leading north to Chesterville, the upper horizon of *Strophomena planiconvexa* occurs 11 feet above the railroad crossing and about 35 feet below the Bellevue or Lower *Platystrophia lynx* horizon. West of Guilford, northwest of the home of George Friedenberg, the upper *Strophomena planiconvexa* horizon is 60 feet above the lower. At the lower horizon, 54 feet above the railroad track, the specimens are small and are associated in the same blocks with *Plectorthis,* small *Platystrophia,* and rare specimens of *Dalmanella multisecta.* The fossil varies in size, form, and coarseness of the radiating plications, all variations being found at both horizons. This is an interesting case of a general recurrence of a species at different elevations. Further search will probably result in finding occasional specimens also at intermediate horizons.

Strophomena planumbona ranges throughout the Waynesville bed, although it is comparatively uncommon in the lower half. At Concord, Kentucky, it is abundant between 30 and 35 feet below the top of the bed. It is comparatively common and widely distributed in the upper third of the Waynesville bed, and also in the Liberty bed. It occurs also sparingly in the Whitewater bed, although *Strophomena vetusta* is far more abundant here. The variety *elongata* is widely distributed in the Waynesville bed. *Strophomena neglecta* occurs at Moores Hill about 15 feet below the top of the Waynesville bed. It is associated with forms not to be distinguished from *Strophomena vetusta,* so that *Strophomena vetusta* apparently begins its range in the upper part of the Waynesville bed although most common and most characteristic of the Whitewater bed. *Strophomena neglecta* occurs also at the Nick Senefeld locality, at the north end of fractional section 26, south of Brookville, 25 feet below the top of the Waynesville bed, and also on Silver creek, opposite the home of Robert Martin, at approximately the same horizon. At Richmond, Indiana, *Strophomena neglecta* occurs sparingly at the top of the Whitewater bed. *Strophomena vetusta* has been found in the lower part of the Madison bed in Indiana. *Strophomena nutans* is widely distributed in the Waynesville bed; one specimen was found in the Liberty bed at Oregonia,

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Ohio, and another in the Whitewater bed at Tate hill, east of Dayton, Ohio. *Strophomena sulcata* occurs in all subdivisions of the Richmond, but it is common only in the upper part of the Waynesville bed and, again, in the upper part of the Whitewater.

7. *Dinorthis retrorsa.*

Dinorthis retrorsa has been considered hitherto one of the most characteristic fossils of the Warren bed. It is found in the Warren bed at numerous localities in southern Indiana, although restricted to a vertical range of only a few inches near the middle of the bed. At Madison, it occurs 47 feet below the top of the Warren; east of Cold Springs station on the Baltimore and Ohio Southwestern it is 32 feet below; east of New Trenton the species ranges from 33 to 35 feet below; half a mile above the mouth of Pipe creek it occurs at least 35 feet below.

Recently a variety of *Dinorthis retrorsa* has been found also in the upper part of the Waynesville bed, about 25 to 30 feet below the top. It occurs 30 feet below the base of the *Hebertella insculpta* layer, directly in front of the home of Nick Senefeld four miles southwest of Brookville, immediately overlying beds containing *Bythopora meeki, Eridotrypa simulatrix, Heterotrypa prolifica, Homotrypa flabellaris,* and *Nicholsonella tenera. Dinorthis retrorsa* was found loose 25 feet below the top of the Waynesville bed at the home of William Bauman, three miles southwest of Brookville. About half a mile above the mouth of Silver creek, opposite the home of Robert Martin, it occurs 47 feet above the creek and 17 feet below the top of the exposure, all of Waynesville age. Here *Bythopora meeki, Callopora subnodsa, Hetrotrypa prolifica, Monotrypella quadrata, Nicholsonella tenera,* and *Spatiopora montifera* were found immediately below this upper *Dinorthis retrorsa* horizon. The top of the Waynesville bed was not exposed. At all Waynesville localities specimens are rare; the valves are usually separated; they differ from the Warren bed forms in the smaller number and greater width of the radiating plications. The Warren form was described by Hall as *Dinorthis carleyi*; a more careful discrimination between Ordovician faunas will probably lead to the revival of Hall's name for the Warren form.

8. Leptaena rhomboidalis.

Leptaena rhomboidalis ranges in the Warren bed of Warren county, Ohio, from three to four feet beneath the *Dinorthis retrorsa* horizon to a short distance above this horizon. It occurs at the same horizon in Indiana, on Big Cedar creek in Franklin county and a mile southeast of Sparta. However, it is abundant and widely distributed only in the upper third of the Waynesville bed. At the Bauman locality, three miles southwest of Brookville, it makes its appearance at the upper *Dinorthis retrorsa* horizon, becomes abundant 10 feet higher, and extends through the *Hebertella insculpta* layer. It makes its appearance at the upper *D. retrorsa* horizon also along Silver creek, half a mile east of Dunlapsville. A mile and a half west of Blue creek postoffice, east of the creek, it is found in the *Hebertella insculpta* layer. South of St. Leon it is abundant for five feet above the *Hebertella insculpta* layer, immediately below the *Plectambonites sericeus* horizon. Occasionally specimens are found at the top of the Whitewater bed at Richmond.

9. Rhynchotrema dentatum, Rh. capax.

Another fossil showing recurrence at different elevations is *Rhynchotrema dentatum*. A variety with fewer and more angular plications occurs in the Warren bed, 23 feet below the lowest strata definitely recognized as Richmond, half a mile southwest of Howard Mill, in Kentucky. The typical form occurs near the top of the Waynesville bed at Versailles and at Metamora. It is rather common in the upper Whitewater beds at Richmond and east of Dayton, Ohio. *Rhynchotrema capax* occurs at Madison seven feet above the massive coral layer at the base of the Madison bed. It occurs much more abundantly in the other subdivisions of the Richmond.

10. Plectambonites sericeus.

Plectambonites sericeus occurs occasionally near the base of the Waynesville bed west of Oxford, Ohio. It is abundant a short distance above the *Hebertella insculpta* layer in the Liberty bed.

11. Platystrophia lynx.

In southern Indiana, and in the adjacent parts of Kentucky, *Platystrophia lynx* is very abundant in the Bellevue bed. In Ohio, it occurs occasionally in the Fairmount, Belle-

vue, and Corryville horizons but is not common until the Mount Auburn bed is reached. It occurs in the Mount Auburn bed also in Indiana, but, except in the neighborhood of Madison, it appears to be very rare at this upper horizon. In Ohio, specimens are known even as far up as the middle of the Warren bed. Many of the gerontic Mt. Auburn specimens in Ohio are characterized by the possession of a remarkably short hinge line, resulting in a more globose form for the shell.

12. *Streptelasma, Heterospongia, Beatricea.*

Streptelasma rusticum, or rather the form which passes under this name in Ohio and Indiana, occurs at Concord, Kentucky, at 47 feet and again at 58 feet beneath the base of the *Hebertella insculpta* layer, while *Dalmanella jugosa* is found in abundance only between 44 and 28 feet beneath this layer. *Heterospongia*, a branching form of unknown affinities, occurs at Madison eight feet above the base of the Madison bed; at Versailles it occurs at the base and also two feet beneath this bed; along Elkhorn creek near Richmond it occurs in the Madison bed about 38 feet below the top. A large typical specimen of *Beatricea undulata* was found immediately above the massive coral layer at the base of the Madison bed [illegible] Indiana.

EARTHQUAKES IN SOCORRO, NEW MEXICO.

By [illegible] M. [illegible], Jr., Socorro, New Mexico.

[illegible] earthquake shocks have been felt in Socorro [illegible] Seismographs have therefore [illegible] the New Mexico School [illegible] investigating these phenomena. [illegible] earthquake which [illegible] night of March 8. [illegible] m., January 19, [illegible] objects back and [illegible] sound like [illegible] same night. [illegible] 30th of Jan- [illegible] 11:30 p. m. [illegible] were three [illegible] was on the

eighth of March at 12:26 a. m. The direction of the movement of the earth-wave during this shock was recorded by the writer's seismograph and was found to be an almost true east and west movement, the motion being first toward the east and then to the west. Though the pendulum swung outward and back, making two complete vibrations, and returned to the centre, it is probable that there was but one vibration-wave instead of a double rocking motion. This is probable from the very fine wire used and the length of the pendulum which would of itself through momentum be carried out and back through the sand bed after the initial jar had passed.

Upon investigation we find that there have been a number of earthquake shocks in this immediate vicinity at various intervals during the past and some have been quite violent. According to the most reliable evidence at hand from one of the oldest residents here there was a strong earthquake on the twenty-eighth of April, 1868, and again in April, 1869. This latter was the most serious known here. This earthquake shock affected the water flow in the Socorro springs at the base of Socorro mountain. Prior to this disturbance the water flowed most rapidly from the southwest corner of the wet area about the springs. After the jar it shifted to the north end of the water-bearing zone where it still issues forth in abundance, but not as strongly as it used to in the area farther south. Furthermore after this earthquake the water became muddy and of a rusty color and remained so for many weeks.

The next violent shock occurred on the sixth of July, 1886, when the County Commissioners were in session at the court house. There was a heavy rumbling sound preceding the jar and this was followed by so sharp a rocking of the building that the men endeavored to rush out of doors for safety. Fortunately the vibrations quickly passed and the building remained.

Again in 1897 another earthquake was felt which is distinctly remembered by many persons now residing here. This was sufficient in strength to overturn chairs and small objects. One man crossing the plaza says that the ground seemed to roll towards him and he was forced to stop and sit down until the motion passed.

The above records are sufficient to show that Socorro is in a belt of crustal disturbances which, while they are not violent enough to render the region in any sense unsafe, yet they may be pronounced enough to be worth careful study and should be accurately measured by instruments prepared for that purpose. With the present improvements made in the seismographs in the basement of the School of Mines we shall be in better shape to record such earth tremors should they continue. There seems to be no record of any damage to public or private property, however, although the recent shocks have been so pronounced that people are awakened from sound slumber when they occur.

All these jars are of short duration, come at irregular intervals, and the more violent appear to be followed by a number of minor tremors which are more or less distinct. The turbidity of the waters in Socorro springs in 1869 and the number of fault planes found on Socorro mountain go far to substantiate the hypothesis that these earthquakes are due to local displacements in Socorro mountain and its outliers. One such fault is visible close to the Magdalena railroad track as it bends around the mountain at the arroyo crossing a few miles from Socorro. These slippings are presumably going on slowly with now and then a sudden displacement strongly marked which results in these local earthquakes. It is quite likely that the region is slowly uplifting which assists in preserving the rugged topography of the mountain which is so characteristic. That such elevation is assuredly taking place in the southwest portion of Colorado among the San Juan mountains has already been shown by the geologists of the United States Geological Survey who have studied the district.

THE SACCHAROIDAL SANDSTONE.

By G. C. Broadhead, Columbia, Mo.

In the Missouri geological report published in 1855 professor G. C. Swallow divides the Lower Palaeozoic strata into a series of three sandstones and four limestones to which he applies the term Magnesian limestone series, as follows, beginning at the top:

First Magnesian limestone, 80 to 190 feet.
First, or Saccharoidal, Sandstone, 80 to 125 feet.
Second Magnesian limestone, 150 to 230 feet.
Second Sandstone, 70 feet.
Third Magnesian limestone, 350 feet.
Third Sandstone, 50 feet.
Fourth Magnesian limestone, 300 feet.

With slight changes these divisions are still recognized, and to certain beds, local names have beeen applied.

The Third Sandstone and Fourth Magnesian limestone were recognized by Swallow on the Niaugua and Osage rivers in Camden and Miller counties. Their equivalents may include the lower lead-bearing limestones of Madison and St. Francois counties. Everywhere else they are covered with later sediments. The Third Magnesian limestone is well exposed on the Gasconade river in Maries and Pulaski and on the Osage in Cole, Miller and Morgan. It is the lead-bearing rock of Morgan, Miller and Washington counties. The Second Magnesian is the principal rock in the Missouri bluffs from the western part of St. Charles county to Moniteau, and forms the entire hill at Jefferson city. Certain lead mines in Cole, Maries, Franklin and Jefferson occur in it.

The Saccharoidal sandstone is well exposed for two miles along the Mississippi at and near Crystal city, 35 miles south of St. Louis, where a thickness of 50 feet of pure white sandstone is seen. Forty miles north of St. Louis it is next seen at Westpoint, Illinois, and at Pacific, 35 miles west of St. Louis, it is well exposed.

This sandstone wherever seen is composed of minute round grains of silica sometimes resembling an oölite and cemented by silica paste and rarely by calcite. Analysis of specimens from several places shows it to be over 99 per cent of silica.

It is more often pure white, but sometimes colored by iron oxide. At Crystal city, Pacific, Augusta and Westpoint it is capped by the First Magnesian limestone. The fact of its being so pure and easily crushed caused extensive plate glass works to be constructed at Crystal city and these have now been successfully operated for thirty years. Near Horine in Jefferson county, it is seen 80 feet thick and thence northwest to Pacific it is of frequent occurrence. One hundred feet thickness is exposed at Pacific, the upper seventy-five feet being pure white and easily hauled. There has been a large quantity shipped off from here for the past twenty-five years. At Valley Park, a few miles east, extensive glass works have recently been constructed.

At Gray's summit the Pacific railroad cuts through this sandstone.

On the Missouri river at St. Albans it is the lowest rock seen and at Lefficue Rock it is in the river.

The hill, one mile below Augusta in St. Charles county, shows the following section:

1. 16 feet of Lower Trenton, on the hill top.
2. 94 feet of First Magnesian limestone.
3. 2 feet of coarse calcareous sandstone, somewhat oölitic and enclosing calc spar.
4. 1 foot of earthy oölitic limestone with calc spar.
5. 2 feet of white and brown sandstone, slightly oölitic.
6. 130 feet of white Saccharoidal Sandstone.
7. 2½ feet of chert.
8. 3 feet of dark, rough, mottled magnesian limestone.
9. 38 feet of Second Magnesian limestone, containing some chert and some Cotton rock beds.

A half mile east, along the bluffs, the Second Magnesian limestone dips beneath the horizon and one mile farther the sandstone disappears. From here, as we go west, as far as Boone, the standstone is found near the top of the Missouri bluffs. On Tuque creek, two miles north of Marthasville, it is 127 feet thick and pure white, with the lower beds slightly brown tinged. A cave called "the devil's boot" occurs near Marthasville. From the level surface we descend 30 feet to the floor. We are there in a room 60 feet wide and 150 feet deep, 8 feet high at the entrance and 25 feet high at the farther end. There is a cave near the head of the Dry fork of Charette which has a beautifully ripple marked roof.

On bluffs of Lost creek, Warren county, one and a half miles from the Missouri bottoms, the section shows:

1. 57 feet with outcrops of chert and some sandstone.
2. 20 feet of Devonian limestone.
3. 15 feet of crinoidal limestone.
4. 80 feet of Trenton limestone.
5. 31 feet of First Magnesian limestone.
6. 70 feet of Saccharoidal sandstone.
7. 105 feet of Second Magnesian limestone.

On Charette creek, Warren county, the Saccharoidal sandstone is seen 84 feet thick, the upper part white, the lower brown tinged, and forming very picturesque scenery, and covered with lichens and ferns. Springs of water often issue from the lower beds.

The Saccharoidal sandstone is exposed on most of the streams flowing towards the Missouri in Warren, Montgomery and Calloway. Five miles southwest of High hill, there is a lone hill called the "pinnacle" nearly surrounded by the water of Pinnacle fork. It is 88 feet high, with a width at the bottom of 100 feet, and 540 feet long, the lower 50 feet nearly perpendicular, the upper 12 feet of First Magnesian limestone, that below of sandstone. The lower part of the sandstone is sometimes deeply weathered and forms good shelter for cattle.

On Whitesides branch it forms very picturesque escarpments capped by the First Magnesian limestone. On Dry fork of Lowtre it forms beautiful terraces and escarpments, the upper 4 feet columnar. The columnar was also seen on Lost creek in Warren county and on most of the branches of Loutre river. The best example of this was seen on Whetstone creek west of Loutre.

On the Missouri bluffs, near Portland, there is a shallow cave in sandstone known as Saltpetre cave. Saltpetre has been made here and the walls are coated with a fine white efflorescence.

At the Clatterbuck ford, on Cedar creek, line of Boone and Calloway, the section shows:

1. 52 feet of Devonian limestone and shales.
2. 25 feet of First Magnesian limestone.
3. 30 to 40 feet of Saccharoidal Sandstone.

The Saccharoidal sandstone appears in high lands in many places in Franklin county and is well developed along the Missouri in the northeast part of the county, also in the northwest between St. John and [illegible] creeks, where Dr. Shumard estimated it to be [illegible] feet thick.

On the Missouri [illegible] in the [illegible] of Gasconade and Franklin it has been quarried and used in bridge masonry. From this place I obtained [illegible] orthoceras over 6 inches in diameter with a siphuncle [illegible] an inch in diameter. The specimen was over 2 feet long. Fragments of what may be orthoceratites were also obtained [illegible] inches in diameter.

On the top of the bluffs between Cole's creek and the Gasconade, the upper beds are of a beautiful and somewhat banded pink color. Near this there [illegible] formerly two large tumbled masses of sandstone known as the Little and Big blossom, but the railroad builders blasted them away. Farther west the sandstone is only occasionally seen, as the Second Magnesian limestone more often reaches from the base to the summit of the hills. Wolf's point, [illegible] miles above Jefferson, is the last point where the sandstone is to be seen. The last point west where it is seen on the railroad is near Syracuse. It is found near the Versailles. It is occasionally found on the highlands near the Gasconade for [illegible] miles from its mouth.

At Westpoint, Ill., it forms a flat anticlinal which exposes the rock 75 feet in thickness for a half a mile along the Mississippi.

On the west side of the Mississippi in Lincoln county, Mo., opposite Cap au Grès, the St. Louis limestone lies horizontal, but on the north side of [illegible] the rocks are tilted up at an angle of 80 [illegible] showing the Burlington limestone and still farther [illegible] rocks, including the First Magnesian limestone, [illegible] sandstone and the Second Magnesian. [illegible] valley three miles north. [illegible] occurrence of sandstone [illegible] spoken of is known as the Cap au Grès [illegible] in LaSalle county, Ill., [illegible] Westpoint [illegible] Cap au Grès, thence northwest [illegible] New London, and is [illegible] county. From [illegible] several miles by a

series of sink holes. Through the northern one-half of Lincoln and through Pike and Ralls it approximately follows a ridge about 12 miles from the Mississippi. At Westpoint the axis must be deep down, opposite Cap au Grès and on Sandy creek nearer the surface, and farther north it lies deeper.

The last place where the Saccharoidal sandstone is seen in Missouri is at Jones', near the lines of Pike and Ralls, where the section shows:

1. 6 feet of limestone.
2. 16 feet of drab shaly limestone.
3. 30 feet of First Magnesian limestone.
4. 4 feet of Saccharoidal Sandstone.

From Westpoint the sandstone is not seen again until we enter Wisconsin and Minnesota. At Minneapolis and St. Paul our Saccharoidal sandstone is the well known St. Peter's sandstone. The First Magnesian seems not to be present here, but the Trenton rests directly on the sandstone. In southern Missouri sandstones often occur, and some have been referred to as the Saccharoidal sandstone, but the adjacent strata seem different.

At the Insane Asylum well at St. Louis the Saccharoidal sandstone was reached at a depth of 1462 feet, showing it to occupy the bottom of a basin of that depth whose outer rim appears at the surface 30 to 40 miles distant at Crystal city, Pacific, Augusta and Westpoint. The thickness in the well was found to be 133 feet, or about the same as that which I measured near Augusta upon the surface. From Augusta to Westpoint it is covered by 700 feet of more recent sediments, showing that between Augusta and Westpoint there is a depression or trough over 700 feet deep extending northwest.

A mile below Augusta there formely stood out from the bluffs a pyramid of rock 40 feet high and 10 feet wide at the base—the upper part a few feet of limestone resting on sandstone. This was separated from the bluffs by a few feet and on its top a small cedar grew, hence it was long known as Cedar hill, but the railroad builders have demolished it. A company now operates a quarry a mile below Augusta and they take out and ship off large quantities of the sand. Their place is now known as "Klondike." Specimens from this place show beautifully under a magnifying glass, sometimes a beautiful cross lamination is seen.

At Clayton, St. Louis county, the sandstone is reached in a well at 1145 feet and at Houseman's, near Brentwood, at a little over a 1000 feet depth. Several years ago it was reported that just after a sudden rise in the Missouri water in the Houseman well rose to the surface. Hearing of this, a project was conceived by certain parties to build a dam on the Missouri where the sandstone is at the water's edge, which was a little more than 20 miles distant. The idea was that the water being dammed up around the sandstone it would thoroughly saturate it and the pressure would force it along the strata to near St. Louis, where it could be utilized. Testing a piece of the Klondike rock I found that after remaining in water five days the weight of the rock would be increased about 5 per cent. But the truth remains that within 50 miles of St. Louis there is an inexhaustible supply of the very best sand for making glass, clean, pure, easy to crush and showing over 99 per cent of pure silica.

A REJOINDER TO DR. DALL'S CRITICISM ON DR. SPENCER'S HYPOTHESIS CONCERNING THE LATE UNION OF CUBA WITH FLORIDA.*

By J. W. SPENCER, Washington, D. C.

I have contoured the continental shelf of the Floridian region, with lines from 200 to 500 feet apart.† Thus it has been found the Bahamas and Cuba are on the continuation of the same continental shelf with Florida. I have studied the valleys indenting this shelf, their sizes and gradients as well as their neighboring geological formations. I have seen in these submarine valleys and their tributaries such a close analogy to the barrancas and canyons incising elevated plateaus and descending from them to lower plains, that I have been forced to conclude that they were sculptured by atmospheric agents, and this being the case, they became evidence that the continent stood at a startling elevation in late geological times.

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* "Tertiary Fauna of Florida" by W. H. DALL, *Wagner Free Inst. Sc. III*, 1904, p. 1544.

† "Reconstruction of the Antillean Continent" by J. W. SPENCER, *Bull. Geol. Soc. Am.*, vol. vi, pp. 103-140, Jan., 1895. Also other papers. On the maps, the close contours have not been reproduced, to avoid confusion of the small scale.

Omitting all the evidential facts bearing upon these features, Dr. Dall tells us that he is still "convinced" that they can be otherwise explained, without suggesting in what manner. He fortifies himself with the opinions of his junior colleagues, claiming that they throw "much more light on the subject," of which I can find none. Yet he passes over the testimony of other widely separated, but actual investigators of the subject. He prominently introduces several irrelevant problems, which are not validly pertinent to my hypotheses, and with which I have no occasion to disagree, and these he discusses in such a manner as would appear to me to carry the implication that he has removed by counter evidence the supports of my hypothesis, which implication cannot for a moment be allowed to pass unquestioned. In only one case does he raise a valid objection, which is easily explained not only by my facts, but also by those of another who is a distinguished authority. Finally he proceeds to shatter all physical investigations on the subject by a dogmatic pronunciamentum, which together with his treatment forces me to reply. And in order to make this reply intelligible, I must give a lengthy citation from Dr. Dall's paper, as follows:

1. "Dr. J. W. Spencer has propounded some very startling hypotheses, involving the elevation of some of the Antilles and Florida many thousands of feet, and their submergence within a comparatively recent period of geological time.

2. "By the researches of Prof. R. T. Hill and Mr. T. W. Vaughan much more light has been thrown on the subject.

3. "I am entirely unable to accept Dr. Spencer's hypotheses, while admitting many of the facts he brings forward, I am convinced that they admit of some other explanation. We find in the Oligocene of Bowden land shells belonging to groups peculiar to and now inhabiting the island of Jamaica, which is sufficient evidence that since the era during which the Bowden marl was deposited the island has never been entirely submerged. With Cuba it may be different, though I can hardly bring myself to believe that the peculiar land shell fauna which is so characteristic of that island can have been evolved since the Pleistocene.

4. "The proximity of Cuba to Florida and the fact that the adjacent portions are composed of organic limestones, which has long been known, led to the very natural, but erroneous inference that Cuba and the peninsula were formerly continuous, and that the Florida straits had been cut between by the erosion due to weather and streams, and subsequently by the gulf stream.

[illegible]

The numbering of the paragraphs is mine, given for reference.

As an elevation of about 2174 feet would connect Cuba and the Bahamas with Florida by isthmuses, the evidence of any greater elevation would have to be sought for far beyond the lands of the peninsula, which constitutes Dr. Dall's limitations. The great elevation suggested by the occurrence of the submarine valleys would certainly be startling if contemplated without study. With me the hypothesis was of slow growth as twenty five years ago I began where my friend now appears to be. About 1878, while investigating the problem of the origin of the basins of the great lakes, I found in the works of Dana and Dawson the evidence of a former greater elevation of the continental lands, but it was not until 1889, when I saw no other probable explanation of the submarine valleys, that the hypothesis of a late elevation of even 2000 or 3000 feet was adopted. The same continental shelf extended from the gulf of St. Lawrence to the gulf of Mexico and it was similarly indented with valleys. Yet it was another four years before I ventured to call attention to the continuation of the same features to great depths.† A year later, I published an array

* "High Continental Elevation" etc., by the writer, *Bull. Geol. Soc. Am.*, vol. [illegible], pp. [illegible], 18[illegible].

† "Terrestrial Subsidence S. E. of the Am. Cont.," *Id.*, vol. v, p. 19 with map

of facts and announced my hypothesis,* and since that time have added the results to numerous surveys confirming my belief that the submarine valleys cutting the continental shelf were formed by atmospheric agents. And I hope to revise the whole subject, brought down to date, in the near future.

Dr. Dall in paragraph numbered 2 refers to the work by Mr. R. T. Hill, which he says throws "much more light" upon the subject.† From the same paper by Mr. Hill I find a confirmation of (a) my previous observations upon the enormous amount of denudation of the white limestones since their uplift with moderate dislocation; (b) the subsequent terracing (which means both subsidence and re-elevation) high ‡ above the present shore line and (c) the remarkable horizontality of the late epeirogenic movements. He also shows how the terraces have been incised by gorges and canyons, but he does not follow these features below sea-level. However, I could not find anywhere that he had thrown any light upon the error or extravagance of my hypothesis as may be inferred when Dr. Dall says that he has thrown "much more light on the subject." That I am right in this contradiction is shown by Mr. Hill's own words. He says: "It might be alleged that all the ancient topography, *showing subsidence is still beneath the ocean level. . . . The submarine topography however is not within the province of this paper.*" Thus it may be seen that Mr. Hill has not studied the very features upon which my hypothesis has been based and consequently he is not in a position to throw any light upon the subject in any way, yet he ventures an opinion thus: *"Without committing myself to an emphatic negation as yet, I must confess . . . I seriously doubt its existence"* (that is, late subsidence), and such an unsupported opinion Dr. Dall accepts as authority. Nor have I been able to find any proof to the contrary furnished by Mr. Vaughan.

While speaking of Mr. Hill, I shall now improve the opportunity of correcting Mr. Hill's measurement of the thickness of the Tertiary limestones at Mantanzas (in the Yumuri can-

* "Reconstruction of the Antillean Continent" by the same, *Id.*, vol. vi, pp. 103 140, Jan., 1895.

† *Bull. Mus. Comp. Zool.*, vol. xvi, pp. 243-288, 1885. MR. HILL was sent to Cuba by PROF. A. AGASSIZ in 1894 to study the raised coral reefs and arrived in Havana just as I was leaving the island.

‡ Also: "Geographical Evolution of Cuba" by J. W. SPENCER, *Bull. Geol. Soc. Am.*, vol. vii, 1895, see page 87.

yon). Here he gives the thickness at 800 feet. The section along the canyon is almost directly across the strata, which dips uniformly at a moderate angle. It shows an unconformity near the top and another at the inner end of the canyon, and a little beyond there is a fault; above which I measured the thickness and found it to be 1700 feet, and if the beds are not repeated at the fault, it was estimated that several hundred feet more would have to be added.* This correction is important, as it shows that the limestones here have about the same development as is now known to obtain in southern Florida on one side and in Jamaica on the other; and it throws more light on the amount of denudation of the neighboring hills. Furthermore, the discrepancy in his measurement does not strengthen the value of Mr. Hill's undigested opinion, as above pointed out.

As expressed in the beginning of paragraph No. 3, I could not object to Dr. Dall's dissent from my conclusions (though I should prefer him to accept them), provided he had attempted to show some other feasible explanation of the phenomena, which he says he is "convinced that they admit" of.

In the latter part of paragraph 3 and in No. 4 Dr. Dall cites evidence that Jamaica and Cuba have not been entirely submerged in later geological days. The introduction of this topic has no bearing upon my hypothesis, and its treatment is liable to leave the impression that here is a strong point against my conclusions. The same infelicitous treatment is a prominent feature of other paragraphs. In Cuba, the terraces and sea caves at about 400, 700 and 1000-1100 feet suggest that Central Cuba was so submerged as to be represented by only a few small islands, though Dr. Dall fails to use such evidence of partial submergence in his paragraph 5. It may be added that these recent terraces could not date to the original uplift of the limestones, which even near by in places have been entirely denuded away.

With the cited correlations of Mr. Vaughan (in paragraph 6), I know of no reason to dissent, but when the heights of the coral reefs are mentioned as occurring to only 40 feet, the one inference to be drawn is that this slight change of level is all that is recorded, while in reality living species of mollusks oc-

* "Geological Evolution of Cuba," cited before, page 76.

cur in beds to an elevation of 150 feet or more, as Dr. Dall would have seen had he referred to my work on Cuba (p. 83). And these fossils, from a point nearly opposite the end of Florida, were determined by Dr. Dall's colleague under his own direction.

The first real objection, and indeed the only one, appears in No. 7, and it is a comfort to reply to it in place of warding off intangible inferences. Dr. Dall says that with an elevation of 5000-6000 feet the plateau of Florida would have been furrowed into canyons, of which none are seen in southern Florida. Certainly in the very low peninsula, such do not form a feature. An elevation of 2100 feet would connect the islands with the continent, and to this amount I shall here confine myself. An uplift of even this much would extend the land far beyond the boundaries of my critic's limitations.

With atmospheric action on such a raised plateau, it becomes dissected, with remnants intact, until the features grow old when only ridges and valleys are left. I had seen in the Floridian channel and its tributaries such dissection, with Florida one of the remnants of the original plateau. My observations of the erosion features of high plateaus, which are not of great antiquity, show that above the head of the incising valleys the surface may show no depressions or only shallow channels. So also the canyons or deep valleys should be found nearer the edge of the continental shelf than the now very low plains of southern Florida, to which Dr. Dall seeks to imit the evidence. Even here the surface has been levelled over by coral reefs or sand accumulations formed since any sculpturing of the Floridian plateau according to my hypothesis. This is confirmed by professor N. S. Shaler who finds great changes of level as shown by the following quotations: "The coast line exhibits a number of flooded valleys . . . some of these channels . . . are now completely filled with sand plains . . . evidently of considerable depth. It is tolerably evident indeed, that if the recent deposits . . . were removed the surface of the Cretaceous and Tertiary beds would be found deeply scarred by gorge-like valleys."*

The above quotation refers to the surface sculpturing, but professor Shaler shows in evidence of a great elevation of the

* *Bull. Geol. Soc. Am.*, vol. vi, p. 154.

peninsula the occurrence of deep subterranean channels in the Tertiary limestone.

He says, after stating that the water of the subterranean drainage comes from considerable depths:

"There is no way in which we can account for the excavation of the subterranean channels . . . except by the supposition that they were made as caverns in the limestone rock, with all their parts above the erosion base level. We have to suppose considerable subsidence to account for these inverted syphons. It is, indeed, not likely that soundings would give evidence of value as to the original horizontal plain of the exit, for under the existing conditions the channels would be filled in." *

He further states that the water coming from depths of at least 800 feet in wells, has displaced the original salt water, indicating a recent elevation to at least this amount. We know of no reason why it should be so limited, as the rock favorable for the production of such channels reaches to an ascertained depth of over 2000 feet. It is also well known that these limestones favor the formation of subterranean drainage channels in place of canyons and valleys, thereby removing the necessity of such valleys as Dr. Dall demands.

Thus Dr. Dall's only real argument against my hypothesis (of a late Tertiary or early Pleistocene connection of Florida and Cuba) and his own opinion that the oscillations of Florida have not exceeded 50-100 feet are not supported when the facts are looked into, nor are his conclusions sustained notwithstanding the opinions of his associates, as shown above. These gentlemen having been referred to, I may be permitted to mention the results of independent and actual workers in the same line of investigations as my own.

In America, on the Pacific coast, professor George Davidson,† and on the Atlantic side Dr. Warren Upham,‡ almost simultaneously with myself interpreted the submarine valleys in the continental shelf as submerged land features. Mr. A. Lindenkohl* had brought to light the deep canyon of the Hudson river, showing that the region has lately been depressed to a much greater depth than that which divides Florida from

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* *Id.*, pp. 154-155.

† *Bull. Cal. Acad. Sci.*, vol. ii, 1887, pp. 265, and Ap. 13. Rep., *U. S. Coast Surv.* for 1887 (1889).

‡ *Bull. Geol. Soc. Am.*, vol. i, 1889, pp. 563-567, and in *Geol. Mag. Lond.*, Dec. 3, 1890, vol. vii, p. 492.

Cuba, and yet it is cut in the continental shelf substantially submerged to the same depth in that region as it is off Florida and the islands.

On the European side of the Atlantic, professor Edward Hull (the retired Director of the Geological Survey of Ireland, and author of the Geology of Palestine including that of the complex Jordan—Akabah valley) has pursued the same methods of study and interpretation of the submarine valleys as myself, and has published numerous papers on those off the European coast.* One of the most important of his drowned valleys was discovered by A. Saint Clair Deville. Hull's conclusions are supported by professor R. Ethridge, another paleontologists, who pronounces them as "fully demonstrated," thus accepting geomorphic evidence of a land feature without the aid of fossils. Professor Hull's conclusions and those of his supporters are applicable to my methods, which professor Hull freely recognizes.

I shall now refer to another epoch-making work, a quarto monograph just published by professor Fridhjof Nansen† (the greatest Arctic explorer), on the continental shelves and drowned valleys, not merely of the Arctic region, but also of the north Atlantic, including part of the American side. Writing of the former elevation of some of the now sunken plains, he says:

"The drowned valleys and fjords at many places make this highly probable, and at some places . . . there seems no other feasible explanation to be found. Some drowned river valleys on the American side of the Atlantic seem perhaps to give still better evidence of such a recent elevation. . . . Although Spencer's descriptions of the drowned valleys (i.e. southeast coast of the U. S. and in the West Indies) may often be based on too few and scanty soundings to be absolutely certain, there are evidently a good many submarine features in this region which cannot easily be otherwise explained, and which indicate vertical oscillations of great amplitude of the shore line as Prof. Spencer has pointed out." ‡

Dr. Dall's long studies of the Tertiary mollusks seem to have made him overlook the import of the hollows and gullies in the older Tertiary limestones of Florida, which are more

* In a series of papers published by the Victoria Institute (1896-1902).

† The Norwegian North Polar Expedition (1893-1896), vol. iv. (XIII "The Bathymetrical features of the North Polar Seas, with a Discussion of the Continental Shelves and previous Oscillations of the Shore-line" by FRIDHJOF NANSEN, *Quarto*, pp. 1-232, plates 1-28, Christiania, 1904).

‡ *Op. cit.*, p. 192.

or less filled up with recent mud and sand accumulations. He has entirely passed over the evidence of the subterranean channels, which professor Shaler considers as proof of a recent elevation of more than 800 feet in place of 50-100 feet given by Dall as a maximum. Strengthening himself with the opinions of his own or colleagues unsupported by evidence, he brushes aside the phenomena of the drowned valleys of the continental shelf without considering them. Even in his own palaeontological work he admits there are uncertainties in the correlations. And he has even stated that "beyond question" certain beds are below the newer Pliocene* and yet these contain a rich mammalian fauna of the later Pleistocene period (belonging to the Equus beds). While I have now twice passed unnoticed his criticisms, a reply has become necessary, and from all the things set forth I am compelled to pronounce that his arrogant dictum—that the late connection of Cuba and Florida is "inconceivable" and "incompatible" with facts in any part of Florida—has not been sustained by any evidence which he has shown, and indeed I have failed to find any geological, physiographic, or paleontological features incompatible with my general hypotheses, though these may be modified in the future and extended. Indeed they seem necessary for the explanation of several features which I gather from Dr. Dall: such as the filled superficial gullies, the change from the warm Oligocene to the cold Miocene waters, the Pacific types of the Miocene of Galveston, problems of the bone beds, etc. Then a number of questions we might ask, such as what part of the system does the Miocene sheet of Florida represent? or where is the evidence of the earlier warmer epoch of the Miocene as in Europe, and how are time correlations made with the Arctic Miocene? This case, like others, may serve to show that a specialist, however distinguished in his own branch, cannot be relied on as an authority beyond the valid evidence adduced.

During the ten years since writing the paper suggesting the connection of Cuba with Florida, much additional evidence bearing directly and indirectly upon the question has been obtained, confirming my views. I have also considered in the fullest manner the probability of the submarine valleys being

* Bull. 84, U. S. Geol. Surv., p. 133.

due to open faults, not sculptured by atmospheric erosion, without finding a vestige of possibility in such explanation. But this whole question will be discussed again from the evidence now obtained.

REVIEW OF RECENT GEOLOGICAL LITERATURE.

Geological Survey of New Jersey, Annual Report of the State Geologist for the Year 1903. HENRY B. KUMMEL. Pages xxxvi, 132; with 14 plates. Trenton, N. J., 1904.

Besides the administrative report, noting the work of the last year, this volume contains the following five papers: 1. Report on a proposed Tide Waterway between Bay Head and Manasquan Inlet, by C. C. Vermeule; 2. The Floods of October, 1903,—Passaic Floods and their Control, by C. C. Vermeule; 3. Forest Fires in New Jersey during 1903, by F. R. Meier; 4. Underground Waters of New Jersey, Wells drilled in 1903, by G. N. Knapp; 5. The Mineral Industry and the Cement Industry, by S. Harbert Hamilton.

The St. Louis Exposition commissioners for this state appropriated $5,000 for a geological exhibit of the state's resources, under the direction of the state geologist and S. H. Hamilton. After the close of the Exposition, this collection of specimens, photographs, maps, etc., will be placed in the State Museum.

It is announced that Prof. R. D. Salisbury during the present year will begin the preparation of a monograph, for this Survey, on the surface geology of southern New Jersey, supplementing his previous Volume V of the series of Final Reports, which treats of the Glacial Geology, limited to the northern part of the state. This work will be welcomed as supplying correlation of the stages of the Glacial period with the stages of the Lafayette and Columbia periods, which have been so well studied along the southern coastal plain from New Jersey to the gulf of Mexico.

During 1903 the mining of iron ore in New Jersey yielded 289,323 tons; and of zinc ore, 279,419 tons. Iron mining is only a half or third of its maxima in former years.; but the zinc mining has gradually advanced to four or five times its amount as it was six to twelve years ago. W. U.

The United States Geological Survey, its Origin, Development, Organization, and Operations. H. C. RIZER, Chief Clerk U. S. G. S., Bulletin No. 227. Pages 205; with 9 plates and 5 figures in the text, both series being mostly maps. Washington, 1904.

The close of a quarter of a century of the existence of this Survey is an opportune occasion for presenting this history and review

of its inception, growth and work accomplished in its numerous and varied departments of surveys and researches in geology, paleontology, hydrography and hydrology, the former dealing with surface waters, and the latter with underground waters; chemical and physical studies, development of mining [illegible], topographic and geologic mapping, publications, etc.

Nearly a third part, or more exactly, 31 per cent. of the entire United States, excepting Alaska, has been topographically mapped by the Survey. Its geological maps, in 100 published folios, cover about 171,000 square miles, or an eighteenth part of the whole national domain, again excepting Alaska and our island possessions. The mapping of our geology may be said to occupy about fifty or a hundred years more.

Prior to June 30, 1903, nearly 2,000,000 copies of the publications of the Survey had been distributed, including the annual reports, monographs, professional papers, bulletins, water supply and irrigation papers, geologic folios and topographic atlas sheets. About two-thirds of this distribution of the Survey publications has been done within the last five years, showing a great increase in the popular use of the results of this national work.

W. U.

Catalogue of the Ward-Coonley Collection of Meteorites. HENRY A. WARD. pp. 113, 9 plates, in red flexible covers. $1.50. Chicago, 1904.

This elegant catalogue is, like its author, sui generis. Other catalogues of meteorites have been printed, but they are the product of public or corporate institutions. Treatises on meteorites have been printed, but they have been extended descriptions and discussions. No catalogue lists so many falls as this. There are four "world collections" of meteorites, that of the British Museum, 577 falls, (catalogue of March, 1904), that of Vienna, 560 according to its last catalogue (Oct., 1902), that of Paris, 466 (catalogue of 1898), and the Ward-Coonley collection, 603 falls.

Dr. Ward gives a sketch of his methods of building up this collection. It is mainly by exchange, but this has been coupled with world-wide travel and liberal purchase. In four years this collection increased 179 falls, or 45 falls per year. Such growth, for a collection which already contained 424 falls, "is unprecedented in the history of meteorite collections."

The work does not go into the chemical or mineralogical details of composition of any of the specimens, but gives interesting statistics of date of fall, where described, name (and its synonyms) and taxonomic classification according to Brezina's system. The catalogue also includes an alphabetical list of all known meteorites, with note of such synonyms as are important, also a list showing the geographical distribution of all known meteorites, the total number being 651. The Ward-Coonley collection embraces 220 falls from North America, 31 from South America, 213 from Europe, 77 from Asia, 27 from Africa,

and 26 from Australasia and the Sandwich Islands. Its total weight is 5,509 pounds, and the average weight of all kinds is 9$^1/_3$ pounds, the total number of specimens large and small about 1,600.

This collection is now "on deposit" at the American Museum of Natural History, Central Park, New York. N. H. W.

The traces of the mountain building process in the coasts of the Don river between the villages Kletskaia and Trechostrovianskaia (in S. E. Russia), by ALEXANDER W. PAVLOW ("Semlevieoenie," 1902, N. II-III).

The paper contains a brief description of one of the regions of the S. E. Russia studied by the author from the geotectonic side.

The locality in question is the extreme eastern part of the Don river, where the river sharply changes its course from the eastern direction to the southwestern (a little northerly of the village Trechostrovianskaïa). The investigations of the author show, that the series of Carboniferous, Jurassic, Cretaceous and, probably, Tertiary rocks, developed in this region, are compressed into a large unsymmetrical anticlinal fold, with strike in a N. E. direction (about 30°). This strike in general coincides with the principal direction of the portion of Don immediately below the extreme eastern point of the river. Thus, the part of the valley (with a W—E direction) is a transversal valley, the parts with the NE direction form a longitudinal.

The described fold must be regarded as an extreme western portion of the *"region of the pericaspian dislocations"* (of the author), connected with the disturbed regions on the rivers Archeda and Medveditza and perhaps with the inclined rocks near the village Tioplowka (in the government of Saratow) situated in the north of the city Saratow.

The western part of the summit level of Volga-Don represents probably the eastern portion of the fold.

According to the author there is no proof of the existence of any fault, as has been supposed by Mr. Leon Dru. If any fault exist, probably one can find it on the summit level of Volga-Don.

Notes on a Section across the Sierra Madre Occidental of Chihuahua and Sinaloa, Mexico. (Am. Inst. Min. Eng., Nov., 1901.)

This paper contains an ideal cross section and description of the Sierra Madre between Parral and the Pacific coast. The results of these observations are new and important. It is shown that the Sierra Madre is not a mountain range, but a great plateau, deeply trenched by river canyons, and bordered westward by a great abfall, with a fringe of mountains carved by erosion from the edge of the plateau. The geologic structure shows a base of eroded Cretaceous shales and limestones, covered by andesitic rocks, partly lava flows, partly fragmental volcanic accumulations, which are cut and metamorphosed by quartsmonzonyte, dioryte, and granite. The eroded surface of these earlier igneous rocks is covered by dacitic and rhy-

olitic rocks, several thousand feet thick, capped by occasional basalt flows.

The recognition of Tertiary granitic rocks in Mexico is entirely new. The order of succession of the igneous rocks is: 1. Andesyte, the oldest; 2. Trachyte; 3. Granitic rocks; 4. Dacyte; 5. Rhyolyte; 6. Basalt.

Harriman Alaska Expedition. Volume IV. Geology and Paleontology. B. K. Emerson, Charles Palache, William H. Dall, E. O. Ulrich and F. H. Knowlton. New York. Doubleday, Page and Company. Roy. Oct., pp. 173, 33 plates.

Including the Introduction by Dr. Gilbert there are eight "parts" of this volume, Dr. Palache furnishing three, viz: General Geology, by B. K. Emerson, 50 pages; The Alaska-Treadwell mine, Geology about Chicagof Cove, and Minerals, 40 pages, by Charles Palache; Neozoic invertebrate fossils, by William H. Dall, 26 pages; Fossils and Age of the Yakutat formation, by E. O. Ulrich, 24 pages; and Fossil Plants from Kukak bay, by F. H. Knowlton, 13 pages.

The descriptions by Dr. Emerson include such observations on the structure as could be made at the various points at which the cruise halted, supplemented by later study of the specimens collected, illustrated by figures and plates. The notes on the microscopic thin sections are valuable and interesting—especially the metamorphic rock described from St. Lawrence island in which the clastic grains of a graywacke are intact in a paste of actinolite needles, the actinolite having resulted from alteration of the original matrix (p. 40). He found but little evidence of rocks older than the Carboniferous, while the Vancouver series of G. M. Dawson, of Triassic, or early Jurassic age, plays a very important part in the geology of the coast even to Plover bay in Siberia. A variety of igneous rocks, in which granite is common, are associated with these sedimentary series.

Mr. Palache's description of the Treadwell mine supplements that of Becker, and is specially full on the new workings opened between 1895 and 1899. The rock of the country is a black slate. The ore consists of "a somewhat silicified sodium-syenyte which has been intruded as a large dike . . . and later charged with gold-bearing pyrite by mineralizing solutions." This syenyte is not much altered even where gold-bearing. It consists essentially of albite with pegmatitic quartz, and orthoclase. The ferromagnesian numerals are lost. The accessories are apatite, titanite and sparingly zircon. The secondary products are pyrite, abundant in sharp crystals, calcite, sericite, epidote zoisite and sagenite groups of rutile. The walls are uniformly black slate, except that in some places a late intrusive, more basic, has entered between the syenyte and the black slate. This, when not altered, resembles gabbro, and so it was named by Becker. The Treadwell Company had running 880 stamps, and were crushing of this ore approximately four tons per day per stamp.

Dr. Palache describes in some detail the geology of a small area at Chicagof cove which is opposite the Shumagin islands, and gives a

geological sketch map. This region is for the most part occupied by a series of Eocene sediments to which he applies the name Stepovak series, and divides them into upper and lower. They have been considerably folded and faulted, and intruded by a laccolitic rock, a dioryte porphyryte that sends off numerous radial dikes into the adjoining sediments. The lower Stepovak beds are coarse breccias and agglomerates and fine tuffs cemented by secondary silica and by other alteration products, the whole plainly of pyroclastic origin, and but slightly fossiliferous. They are hence probably of local and perhaps quite restricted distribution and will be difficult to co-ordinate with any other igneous rock mass in Alaska. The upper beds are evidently of marine deposition, consisting of soft shales, sandstones and grits, with some thin beds of limestone and now and then a chert band. They are the principal rocks of the region, forming the coast line, having a thickness apparently of more than a thousand feet. According to Dr. Dall the fossils found in the Stepovak series denote the Claiborne (Middle Eocene) age.

Dr. Palache describes and figures a laccolith of intrusive rock in the Stepovak series, exposed near the summit of Chicagof peak. The intrusive rock is augite-dioryte-porphyryte, dark colored, gray to greenish-gray and fine-grained with porphyritic crystals of hornblende and labradorite, more rarely of augite. The author speaks of hornblende surrounding pyroxene cores, but "clearly original." From this laccolith numerous radiating dikes pierce the sedimentary rocks, the prevailing type being an alkali-syenyte-porphyry, the porphyritic element being black hornblende, while in the groundmass are crystals of albite, and but rarely an insignificant amount of quartz. Other dikes are petrographically named latyte, hornblende-dacyte, dioryte-aplyte, dioryte-porphyryte, olivine diabase and diabase porphyryte, without chemical analyses.

In the section on *minerals* Dr. Palache enumerates all minerals seen by the party, not including the rock-forming minerals. He modestly states that this catalogue is not extensive, but it contains 33 names.

The invertebrate fossils of the Neozoic are described by Dr. W. H. Dall, the oldest being those of Stepovak bay. The next higher are "logically" the Kenai series on the peninsula separating Port Moller from Herendeen bay immediately to the westward. These are coal-bearing, and are overlain by a thinner series of Miocene age which is also much broken by volcanic dikes and intrusions of lava, found in numerous localities along the north shore of Popof island. An important stratigraphic result of the expedition therefore is the addition of a fully established lower series to the Eocene of Alaska. Of the Stepovak fauna there are 34 species, of which 32 species are from the "upper beds," and two, belonging to Modiolus and Cassis, but unidentifiable as a species, are from the lower, or volcanic beds, of the whole number eleven being described as new.

To the Kenai, or Astoria, series of the Miocene Dr. Dall refers the fossils from the Shumagin islands, immediately south of Stepovak bay,

enumerating not only those recently found, but those previously collected by himself and by Grewingk, making 31 species, 16 more than formerly known.

Certain boulder-clay deposits at Juneau contain Pleistocene fossils, marine invertebrates, to a hight of about 200 feet above present high tide, indicating that the land then was at least 200 feet lower than at present and the climatic conditions somewhat colder. The geological features of this vicinity have been discussed by Mr. Gilbert in vol. iii of this series. There are 19 species of which two are not known in the recent state.

The fossils of the Yakutat formation are discussed by Mr. Ulrich. They are mainly from near Kadiak, on an island off the Alaskan peninsula northeastward from the Shumagin islands, although the name was given by Russell in 1891 to a locality near Hidden Glacier nearly 500 miles to the eastward. These localities are bound together stratigraphically by the occurrence of a fossil of definite character, *Terebellina palachei,* common to them all, although there are 18 species in all, 13 being new. Their upper Liassic age is shown by the direct evidence of four European species characterizing that age, viz: Chondrites divaricatus F.—O., C. alpestris Heer, Helminthopsis magna H. and H. ? labyrinthica H., the latter genus being known only as Liassic. The most of the fossils are fucoids.

F. H. Knowlton describes the fossil plants from Kukak bay situated a little north of west from Kadiak island, of which he enumerates 26, amongst which the confers and the birches prevail. He describes nine new forms, seven are not named specifically being branchlets, seeds, scales, etc., leaving ten species previously known. Without hesitation they are referred to the upper Eocene.

The expedition was an excursion, but with the experienced geologists who composed the party there could hardly be a failure to gather important scientific data. The published volumes bear testimony to the industry with which they studied the regions where the temporary camps were made, and to the skill and learning with which the data are discussed. It is not an exhaustive treatise on the geology of the coasts of Alaska, but it is exhaustive and conclusive on the questions presented for discussion. Its authority will stand probably unimpaired by future observations, and it will have to be consulted by future geologists who attempt to add to the geology of Alaska. N. H. W.

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The Nagagami river and other branches of the Kenogami. (Sum. Rep. Geol. Sur. Can., 1903, pp. 109-120.)

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Eruption of Mauna Loa in 1903. (Am. Geol., vol. 34, p. 62, July, 1904.)

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PERSONAL AND SCIENTIFIC NEWS.

PROF. H. F. OSBORN, now in Europe, will lecture on the evolution of the horse at Cambridge, England.

DR. J. B. HATCHER, of the Carnegie Museum at Pittsburg, Pa., died July 4, of typhoid fever at the age of [illegible] years.

PROFESSOR RAPHAEL P[illegible] is making archæological excavations for the Carnegie Institute in Russian Turkestan.

YALE UNIVERSITY conferred the degree of doctor of laws on president Charles R. Van Hise of the University of Wisconsin.

THE EIGHTH INTERNATIONAL [illegible] which meets in this country in September, will have sessions at Washington, New York, Niagara Falls, [illegible] St. Louis.

THE AMERICAN MUSEUM [illegible] expeditions in the field [illegible] vertebrate paleontology. [illegible] ger, Mr. Barnum Brown and Mr. [illegible]

The Tenth Meeting of the Lake Superior Mining Institute will be held Aug. 16, 17, and 18 at Ironwood, Mich. There will be an excursion to Milwaukee and Chicago. It promises to present a very interesting and valuable program.

According to Dr. J. C. Branner the "stone reefs" of the Brazilian coast are entirely distinct from coral reefs, and are due to lithification of beach sands in place—consolidated sand approaching quartzyte. Their existence forms many of the harbors on which are important cities. They usually are nearer the land than the coral reefs whenever both occur at the same place. They are flat-topped and flush with the surface of the sea at high tide.

According to Professor H. F. Osborn there are in the American Museum of Natural History remains representing upwards of 770 specimens of fossil horses. In 1900 "a herd" of six Pleistocene horses were discovered belonging to the new species *Equus scotti.* Explorations have demonstrated the existence of two and probably three collateral lines of horses contemporaneous with the Protohippus line which is regarded as the lineal ancestor of the true horse.

Mr. Charles Schuchert, Assistant Curator, Division of Stratigraphic Paleontology in the U. S. National Museum since 1894, has been appointed Curator of the Geological Collections in the Peabody Museum and Professor of Paleontology in Yale University, also Professor of Historical Geology and member of the Governing Board of Sheffield Scientific School, succeeding the late professor Charles Emerson Beecher.

During his period of service in Washington Mr. Schuchert has shown himself more than usually efficient, and his loss will be deeply felt.

Professor Schuchert's address after September 1st will be New Haven, Connecticut.

Amygdaloid in Manitoba. According to the last "Summary report" of the Canadian Geological Survey (for 1903) outcrops of copper-bearing amygdaloid have been discovered on lake Manitoba in Manitoba. The strike seems to run SE and NW, rising about ten feet above the general level of the plain with an apparent slight dip toward the west in which direction they run under almost horizontal beds of gypsum. "Cavities near the surface are nearly always empty and lined with a coating of white substance, occasionally they are filled with greenish earth or with crystals of zeolites. Small particles of copper can be seen with the microscope and some copper carbonate. Small areas of jasper conglomerate are associated with the amygdaloid, but their relative position is uncertain."

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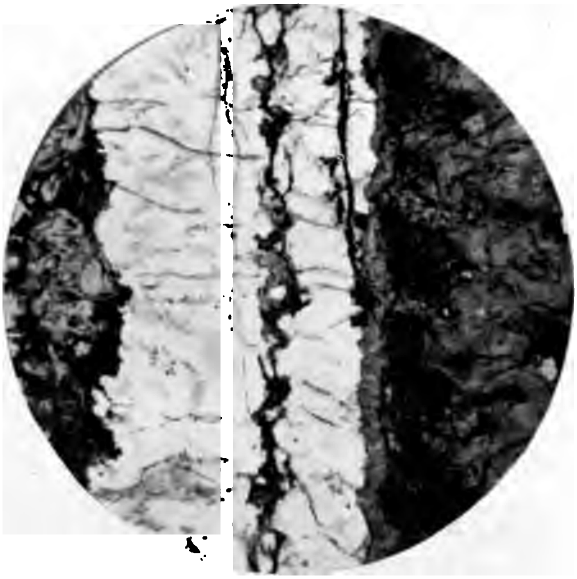

A.

B.

Thin sections of orbicular gabbro of second variety. A. Section of periphery, showing feldspar zone and concentric rings of olivine, which has here altered to actinalite. × 33. B. Section of periphery, with × Nicols, showing irregular orientation of feldspar × 33.

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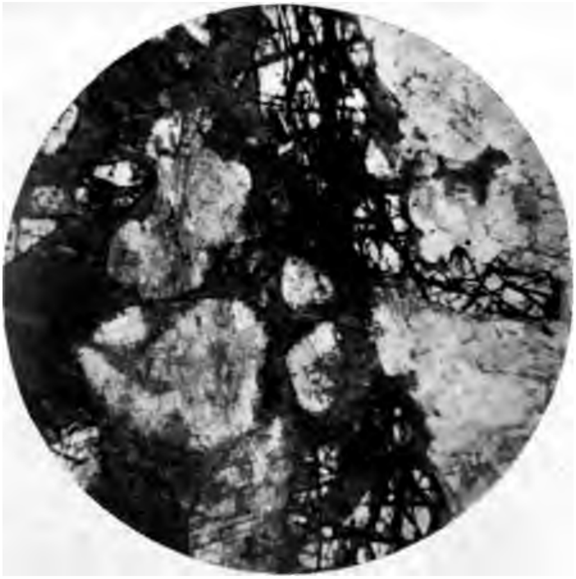
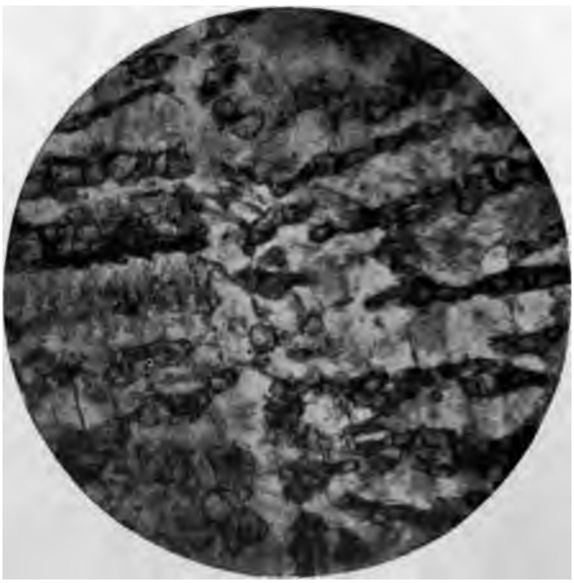


A.



B.

Thin sections of orbicular gabbro of third variety. A. Section of centre of nucleus, showing inclusions of feldspars and olivines in hornblendes. × 60.
B. Section of radial zone showing radiating olivines and concentric ring in which olivine is lacking. × 33.

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Boulder of orbicular gabbro (second variety).

Section of orbicular gabbro (second variety), showing general appearance. White minerals are feldspars. Dark minerals are olivines, hornblendes and hypersthens. Thickness, about 2mm. Nat. size.

Hand specimen of orbicular gabbro of third variety. Natural size.

THE

AMERICAN GEOLOGIST.

VOL. XXXIV. SEPTEMBER, 1904. No. 3.

THE ORBICULAR GABBRO OF DEHESA, CALIFORNIA.*

By H. H. KESSLER and W. R. HAMILTON,
Stanford University, Cal.

PLATES VI–X.

Occurrence. The rock which forms the subject of this paper was first found in 1901, as a small piece of float, beside the road, near Dehesa, by Mr. Marion Powers. This specimen was sent to professor A. C. Lawson at the University of California and was discussed by him in a brief paper before the Cordilleran Section of the Geological Society of America, at its meeting of December, 1901.† Since the work of preparation of the present paper has been completed, there has come from the press, a paper by professor Lawson on the same subject.‡

The orbicular gabbro occurs in a boss of gabbro which broke through the surrounding granite and which forms nearly the whole of the first hill which rises to the northwest of Dehesa post office. This hill is very steep and rises to an elevation of 1800 feet above sea level and 1300 feet above the Sweetwater river, which flows at the base.

The locality is on the El Cajon sheet of the U. S. Geol. Survey, the exact locality being Long. 116° 52′ W., Lat. N. 32° 47′. This gabbro boss has an area of approximately one

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* The authors are indebted to Dr. J. P. Smith, of Stanford University, for advice and assistance.

† On an Orbicular Gabbro from San Diego Co., Cal., by ANDREW C. LAWSON, Berkeley, Calif. *Science*, (New Series), vol. xv, p. 415

‡ The Orbicular Gabbro at Dehesa, San Diego Co., Cal., by ANDREW C. LAWSON. *Bull. Dept. Geol. Univ. Cal.*, vol. iii, No. 17, March, 1904. (The writers had begun preparation of this paper before they knew that the paper of PROF. LAWSON was being prepared.)

square mile. Over only a small area, which is near the centre, are the orbicular rocks found. About two per cent of the boulders in the small area, show the orbicular structure.

Geological relations. The granite through which the gabbro has broken is, with slight variations in petrographical character, continuous over a large part of San Diego Co. Fairbanks* has done some work on the region and he mentions many phases of the crystalline rocks, but no detailed petrographic or chemical analyses have been made of the rocks in the locality.

The granite is evidently older than the gabbro. There is no fusion contact visible. The contact can be easily traced on the surface and is often found to lie in small water courses, showing less resistance to erosion. The gabbro is fresh though considerably shattered, and exists as huge angular boulders lying in irregular heaps and as isolated masses. In no place can it be found in a large mass *in situ.* The mass was evidently consolidated before the uplift, and shattered during that interval. Owing to this shattering of the gabbro mass, the boulders of orbicular gabbro have been isolated. The writer spent several days examining the area and in no place could the orbicular rocks be found in place. It is evident from an examination of the boulders, that the orbicular portion occurred in the original mass as a dyke, the character of the gabbro on either side being identical. In some of the larger boulders it is found as a dyke, from one to eight feet in thickness. In such cases the line between the orbicular portion and the barren portions of the rock is clearly defined. No orbicular rocks were found at any place nearer than 400 feet from the contact with the granite, so it is probably not a contact phenomenon.

General Petrographic Characteristics.

The normal gabbro. The main body of the boss is made up of a coarsely crystalline, mesocratic, hornblende gabbro. The texture varies from microcrystalline to coarsely granitic, with large crystals 10 mm. to 15 mm. in diameter. The most notable petrographic feature is the profusion of these hornblende crystals. Dykes or segregation veins, two to ten inches

* *11th Ann. Report of the Cal State Mining Bureau,* 1893, pp. 76-120.

in thickness are seen in many places, made up almost entirely of black hornblende crystals. Some of these hornblendes were noted nearly four inches in length. They seem to be well distributed over the gabbro area.

A peculiar wavy banding is often seen in the gabbro boulders. It is made up of alternate layers of light and dark minerals. the band usually continuous in width, despite its undulating arrangement. This appears to be *fluxion structure*.

The principal constituents of the gabbro are: plagioclase, hornblende, olivine, hypersthene and oxide of iron.

The feldspar usually predominates, though the hornblende, owing to its resistance to weathering, is the most prominent on the weathered surface. The extinction angles of the feldspar vary 26° to 40°, measured from albite lamellæ. Twinning after the *albite* and *pericline* laws is common. The twins often show evidence of crushing—fraying out or ending abruptly. In some hand specimens the feldspar contains inclusions of olivines. In others the olivines contain the feldspars as inclusions. The former occurrence is the more frequently noted.

The hornblende is of the brown basaltic type. Extinctions c∧c as high as 16° have been noted. It has a strong pleochroism, brown to yellowish. A cleavage angle of 123° was noted in the hand specimen.

Olivine is usually very fresh, but in thin sections taken from near the surface a great variety of decomposition products are seen. Hornblende, actinolite, tremolite, chlorite, iddingsite, serpentine, limonite, and an unidentified member of the sodalite group, were noted as secondary to olivine.

Hypersthene is usually partially uralited, enough of the original hypersthene usually being left to show the origin of the amphibole. In one section the hypersthene was almost completely enveloped in a network of magnetite. In the same section the olivines are also seen to have similar inclusions. This phenomenon was probably caused by the presence of a superabundance of iron when the ferro-magnesian mineral crystallized. The pleochroism of the hypersthene is distinct, green to pink.

Diallage is almost entirely absent. In only one thin section was it noted and in that its identity was not very clearly established.

The orbicular rocks. Three distinct varieties of orbicular structure were noted: one showing neither concentric nor radial structure; another showing concentric, but not radial structure; and a third showing both concentric and radial structure.

The first variety was noted in only the most weathered rocks. It was found farthest up the hillside, the highest boulder being found about 400 feet from the summit, on the south side. It consists of seemingly homogeneous balls which stand out on the weathered surface as balls instead of being seen as rings, such as the other two varieties show. A fracture of the rock merely separates the balls, showing them to be more resistant than the matrix. The balls are made up of finer crystals than the material surrounding them. They are usually about 30 mm. in diameter, but one was found three inches in diameter. In places on the surface of the ground these spheroids are found to be so plentiful as to give the appearance of water-worn pebbles. In the spheroids of this variety the feldspars show evidence of crushing. The olivines occur in rounded grains. There is no development noted, either toward concentric or toward radial structure.

The second variety, of which the largest part of the obicular boulders is composed, consists of an outer ring of feldspar 3 mm. to 4 mm. in thickness and about 40 mm. in diameter (Pls. VIII and IX). This surrounds a nucleus which is seemingly little different from the outer matrix. In the center is found a sponge-like bunch of feldspars. The feldspars in the outer zone have no regular orientation. Concentric rings of olivine are seen, but otherwise the zone is composed of feldspar entirely.

The spheroids are usually round, but are sometimes flattened. In such cases the feldspars show evidence of crushing, denoting that movement of the mass took place after consolidation. There is no suggestion of radial structure in this variety of spheroid. There seems to be no regularity of orientation in any of the feldspars. (Fig. B, Pl. V). The feldspars usually average about 0.4 mm. to 0.5 mm. in diameter. The line between this outer feldspar zone, or periphery, and the darker minerals of the matrix, is clearly defined as is the line between the zone and the nucleus.

This rock has generally a greenish color from the superabundance of green decomposition products of olivine and hypersthene. In the field, rocks were noted with this variety of spheroid and with dykes of hornblendic material cutting through the orbicular portion, and with the hornblendic portion itself orbicular.

The third variety is the rarest of the three. This one is of the same type as the one described in professor Lawson's paper. The outer zone has a distinct radial and concentric structure (Fig. B, Pl. V and Pl. X). It is much wider than the corresponding zone in the second variety, being about 12 mm. to 15 mm. in thickness and about 60 mm. in diameter. The spheroids are best seen on a weathered or a polished surface. From an examination of the hand-specimen, the observer would suppose the orientation of the feldspars to be radial. Upon a microscopical examination of a thin section, however, the radial appearance is seen to be due to radiating olivines, whereas no definite orientation whatever has been noted in the feldspars. The nucleus is made up of about equal quantities of light and dark minerals, with the dark hornblende predominating. Feldspars are found in the nucleus as inclusions in hornblende (Fig. A, Pl. VII). Where it occurs as such it has a corroded surface and a roundish outline, probably showing that there was a partial resolution of the feldspars in the original fluid magma. These corroded feldspars appear snow-white when seen in the hand-specimen.

The feldspars give extinction angles which vary from 27° to 40°, measured from the albite lamellæ. In the hand-specimen they often show iridescence, showing a beautiful play of colors similar to that seen in the typical labradorite. Their average size is about 0.22 mm. in diameter.

The olivines are long, lathe-shaped aggregates varying in width from 0.03 mm. to 0.20 mm. and in length from 0.8 mm. to 1.4 mm. At certain intervals can be seen concentric rings in which the olivine is lacking (Fig. B, Pl. VII). These rings are about 0.06 mm. in width. The olivines nearly all contain minute inclusions of feldspar averaging about 0.006 mm. in diameter. This shows that the feldspars already existed as such when the radial arrangement of the olivines took place. The olivine is very fresh and has high interference colors.

The relief is high (Fig. B, Pl. VII). The only alteration products noted are serpentine and occasionally hornblende.

Hypersthene occurs in irregular patches associated with olivine and magnetite. Pleochroism is distinct, pale greenish to pink. The extinction is always parallel to the pinacoidal cleavages.

Hornblende is very common in this rock, both in the nucleus and in the matrix which separates the spheroids. The black minerals are well shown in the figure of the hand specimen.

The periphery merges into the surrounding rockmass. There is no abrupt change in the preceding variety. The change from the radial zone to the nucleus is also gradual.

Chemical Properties.

One partial analysis was made of the obicular gabbro of the third variety. Samples were taken from all parts of the fresh surface. The sample was made to represent, as nearly as possible, the entire composition of the rock. With this analysis are given, for comparison, the analysis of a spheroid given by professor Lawson*, and a partial analysis of an orbicular noryte from Plumas Co., Cal., described by Mr. H. W. Turner.† These are seen below:

	I.	II.	III.
SiO_2	43.28	40.08	45.92
Al_2O_3		22.86	
FeO / Fe_2O_3	33.69	11.96	
CaO	12.02	11.41	9.61
MgO	11.77	12.40	13.85
Na_2O		1.26	.71
K_2O		.38	.10

I. Orbicular gabbro, Dehesa. Horowitz, analyst.
II. Spheroid of orbicular gabbro, Dehesa. Howson, analyst.
III. Orbicular noryte, Plumas Co. Steiger, analyst.

A comparison of I and II does not show any great change in the chemical contents between the spheroid and the matrix. That the matrix is higher in SiO_2 may be due to the fact that the hornblende predominates, while in the spheroid the feldspar predominates. The calcium and magnesium are practi-

* *Loc. cit.*, p. 394.
† *17th Ann. Rept., U. S. Geol. Surv.*, p. 642.

cally the same in both. This similarity in chemical composition seems to denote that the cause which set about the formation of the spheroids was not a chemical phenomenon.

Other Occurrences.

Orbicular granites have been noted in many localities, notably from Slatmossa, Sweden.* Also from Fonni, Sardinia.†

An orbicular granite was described from Quonochontogue Beach, Rhode Island, by J. F. Kemp.‡

This quite closely resembles an appearance, the second variety of spheroid from Dehesa. Another occurrence is described by Hatch, from Mulaghderg, Ireland.§ This resembles the orbicular dioryte of Corsica much more closely than does the gabbro of San Diego, the radial structure being very pronounced. Spheroids in the granites of Sweden were described by Brögger and Backström.‖

A nodular granite from Ontario, has been described by F. D. Adams.¶ This differs from other orbicular granites in that there is no pronounced radial or concentric structure. The same is true of the "pudding" or "prune" granite of Vermont.°

Orbicular dioryte is represented best in the type locality, Corsica. It was described by Vogelsang.** Another example was reported from Rattlesnake Bar, Eldorado Co., Cal., by Vom Rath.*** A specimen from this locality may be seen in the California State Mining Bureau Museum in San Francisco, Cal.

Orbicular gabbros have been reported from Romsas, Norway by Chrustschoff,°° and from Willow creek, Cal., by H. W. Turner.†† This is described as an "orbicular rock which contains olivine and iron ore with much rhombic pyroxenes and

* Sitzungsber. d. neiderrhein. Ges., Dec., 1874, p. 206. Also *Rept. Smithsonian Inst.*, 1900, pp. 50, pl. 6.

† "Sur les nodules de la Granitite de Ghestonai pres Fonni (Sardaique)" *Bull. de la Soc. Min., France, tome X* (1887), pp. 57-63.

‡ *Trans. N. Y. Acad. Sci.*, vol. xii, pp. 140-144, Pl. XI, 1894,

§ *Quar. Jour. Geol. Soc.*, vol. xliv, p. 548.

‖ *Geol. Forem. Stockl. Forhandl.*, No. 110, Bd. ix, Haft. 5, p. 307.

¶ *Bull. Geol. Soc. America*, vol. ix, 1898, p. 163.

° *Geol, of Vermont*, vol. ii, p. 564, 1861.

** *Sitzungsber. d. neiderrhein. Ges.*, 1862, vol. xix, p. 185.

*** *Sitzungsber. d. neiderrhein. Ges. zu Bonn*, 1884, p. 206.

°° Buber holocyrstalline macrovariolitische Gesteine, von Dr. K. von Chrustschoff, St. Petersburg.

†† *14th Ann. Rept. U. S. Geol. Surv.*, p. 474. Also *17th Ann. Rept. U. S Geol. Surv.*, p. 642, Pl. XXX.

anorthite, but the average rock of the area is a normal gabbro composed of monoclinic pyroxene, brown hornblende and basic plagioclase. In some specimens there are large porphyritic hornblendes more than an inch long." Except for the monoclinic pyroxenes, the noryte of Willow Creek is very similar to that of Dehesa. A partial analysis of the former shows a close resemblance to an analysis of the latter.

Dr. Chrustschoff, who has made a study of many forms of nodules in crystalline rocks, has divided them into four classes:

1. Concentric, spheroidal and concretionary growths about foreign inclusions.

2. Nodular growths about fragments of secretions or inclusions which latter are often partially or wholly redissolved.

3. Groups of so-called pudding granites where the structure is due to a simple concretionary action, set up in the magma during its normal crystallization.

4. Primary structural forms of the magma or endomorphic contact products.*

The explanation of Vogelsang,† in his discussion of the dioryte of Corsica, is as follows:

"When a molten magma consolidates, an irregular (ungeleichmässig) cooling may produce greater contraction of the mass at certain points; and this may lead later on to a spheroidal separation. If this condition is arrived at after the point of consolidation of the several minerals has been passed, and, therefore after their separation is complete, we get, indeed, a concentrically laminated body, but one without definite arrangement of the constituents; this is the well known spheroidal structure of many eruptive rocks. If on the other hand, the tendency to form spheroids is developed during the period in which a differentiation of the magma into its various minerals can still take place, the latter will undergo a definite arrangement with regard to the central point."

It would seem that we have the two cases represented in the forms of orbicular gabbro from San Diego. The fact, however, that the boulders are not in place, makes it impossible to conjecture on the position of the different varieties with reference to the cooling surface. It is evident that the conditions were not the same when the different varieties were formed.

* Memoires del. Academie Imperiale des Sciences de St. Petersbourg, VII Series, tome xlii, No. 3. (Quoted from F. D. ADAMS' paper, the originial by DR. CHRUTSCHOFF is not accessible to the writers.)

† *Loc. cit.*

TECTONIC GEOGRAPHY OF EASTERN ASIA. II.

Reviews and Translations by WILLIAM HERBERT HOBBS, Madison, Wis.

In an earlier article* has been summarized the first of a series of three papers by Baron von Richthofen, dealing with the geomorphology of eastern Asia.† It was shown by this authority that the course of the mountain ranges which rise abruptly to form the western margin of the coast plains of eastern Asia, extend in a series of zigzags made up of meridional and equatorial components, and that these ranges form the boundary of the high plateau to the westward which is separated into crustal blocks whose approximate dimensions are given by the zigzags themselves. The general direction of the series of zigzags is that of a great circle whose course is about parallel to the general trend of the coast line, the broken crescents formed by the blending of the meridional with the equatorial components being always convex towards the ocean. The elements of the zigzags are found to correspond in position to normal faults of large throw, the orographic blocks which they outline being always downthrown on the eastern, convex, or ocean side.

In the second of the series of papers‡, von Richthofen shows that the scalloped eastern boundary of the Eurasian continent, while parallel to the mountain ranges near the coast is not an expression of their folding. Of the morphological relations he says:

(a) The series of crescent-shaped marginal zones of crustal blocks convex to the southeastward which run through continental east Asia from the peninsula of Tschuktschen to the northwest of Tongking, and are characterized throughout the entire line by the sinking in of those portions of the earth's crust which lie to the eastward, are followed in the direction of the ocean by a second series of homologously constituted crescentic blocks which form the oceanic border of eastern Asia. The parts of the earth's crust which are broken down along them lie to the eastward in the bottoms of the seas. On the Stanowoi coast the

* This journal, August, 1904.

† FERDINAND FREIHERR VON RICHTHOFEN. Über Gestalt und Gliederung einer Grundlinie in der Morphologie Ost-Asiens. Sitzungerber. d. k. preuss. Akad. d. Wiss. z. Berlin, vol. xxxix, 1900, pp. 888-925.

‡ FERDINAND FREIHERR VON RICHTHOFEN. Geomorphologische Studien aus Ostasien. II. Gestalt und Gleiderung der ostasiatischen Kustenbogen. Sitzungsber. d. k. preuss. Akad. d. Wiss. z, Berlin, vol. xxxvi, 1901, pp. 782-808.

two series of crescents fall together, for the sea extends inward to the fronts of the interior series. The members of the second series forming the marginal zone of the continent begin at Cape St. Alexander in 54° 15' N. and terminate at Cape St. Jacques in 10° 40' N. The island crescents which project above the sea belong in a series still further to seaward in the complex of the east Asiatic depressions continued beneath the sea and can here be given only an occasional mention.

(b) If one takes into consideration the coast line represented upon maps as an enveloping contour line of the steep wall bounding the individual blocks, there is indicated by it in the sharpest manner the general form as well as each individual division in it. Furthermore the sculpture of the coast may be recognized in the coast line. Four great coast crescents appear distinctly. They have been designated above as the Tungusian, the Korean, the Chinese, and the Annamitic. The third and fourth are completely closed; the first has a small gap to be explained by local submergence; the third is only retained in one fragment. We have ventured to complete it hypothetically through interpolation, according to the scheme indicated by the interior and the coastal crescents.

(c) The lineal form of each individual crescent of this coast series approaches more the form of a circle than is the case with the interior crustal blocks. In the case of each of the latter there could be recognized two extended arms of crescentic form joined to one another, which can be considered as the meridional and equatorial arms. From the Aldan range to Yunnan an approximate parallelism controls these two elements in so far as the meridional stretches follow the mean direction N. to N.E., and the equatorial are controlled by the Sinian direction W-S.W. to E.N.E. In the case of the coastal crescents the analogy because of the similar designation may be retained, but with the modification that rectilinear stretches of coast of more than 200 kilometers are rare, while the convex curvature in the direction of the sea obtains in all parts; also with the further modification that each individual coast crescent has a much greater individuality respecting its inclination to the meridian, that is to say, the air line of its beginning and end portions. In form and in position in reference to the continent, the crescents are not equal. They may be separated into two groups, and from two points of view; for similarly constituted are the Tungusian and the Chinese crescents on the one hand, the Korean and the Annamitic on the other. The two former represent, if one glances at the general form of eastern Asia, together with the great double Stanowoi crescent, the fundamental marginal line of the continent; while the two others together with Kamchatka surround projecting peninsulas from the main body. This relation is still doubtful and will here be left out of consideration, as Kamchatka also and the S.E. front range of north Stanowoi will not be drawn into consideration, because of insufficient knowledge of their structure.

(d) The Yellow sea [illegible] of a block enclosed [illegible] which is somewhat more de-

pressed than the other parts of the East Asian steps formerly designated as coastal.

(e) The general form of the interior land blocks lying to the north of the Tsinling mountains, which is conditioned through the general rise of the included land surface in the direction of a more highly elevated border, and the shorter descent, probably depending upon step faulting toward the seaward, is represented in the Tangusian and Korean marginal blocks. The marginal bulging up is lacking to the Chinese crescent, but is present on the other hand in the meridional part of the Annamitic.

The general arrangement of each individual coast crescent is independent of the internal structure as has already been set forth as true of the interior land blocks. But the proportion is a special one in the case of each crescent.

MANNER AND AGE OF THE TECTONIC MOVEMENT.

(a) As little as the crescents of the interior series do the exterior ones correspond morphologically and tectonically with the folding and overthrusting of the connected mountain scallops upon the convex side, though in their linear outlines they more resemble them than those of the former series. In the case of the Tungusian crescent it is not proven that very old, perhaps even Archean, folds do not stand in some relation with its position; but on the one hand parts of it cut too sharply through the axes of folds in order to bring both into complete causal connection; on the other hand it is only one member of a series of externally homologous structures whose form must be referred to a similar action of forces. Since now in the case of the other three crescents a correspondence with the internal structure cannot be made out, we may measure with it the fact that in the case of the Tungusian crescent such a correspondence is in part present, as having a secondary significance only.

(c) The continental mass of eastern Asia may be considered to have been depressed in great blocks. Two of these are distinctly indicated through widely extended crescentic lines in sections depending upon the formation of fractures. The one cause of the phenomenon is to be sought in the combination of two systems of tensional forces of which one was directed eastwards, the other southwards.

If we seek for the cause for the development of the eastwardly directed tension it may be sufficiently given in the depression of the Pacific ocean basin on the border of the continental mass presumedly depending upon isostatic tendencies continuing through long periods. . . . . The Eastern Asiatic festoon of islands appear as the crest of the marginal region of the continental mass arched up through such upward working stresses. But since they bear the character of the inner side of fold mountains, the folded outer zone must be sought first in the descent toward the oceanic depth. The existence of other still deeper lying crescents projecting only in small island peaks and otherwise still hidden beneath the surface of the sea, as they stand forth upon bathe-

metric maps shows the conclusion that the same tendency has been present operating in this part also of the earth's crust since the earliest times. For the explanation of the equatorially directed tension and movement of great parts of the earth's crust in Asia from Kwenlun Tsinling on, the same ground does not appear; it may perhaps be explained, if doubtfully, through changes in the velocity of rotation of the earth and the displacement of mass condition thereby."

In connection with the above statements by von Richthofen it is interesting to note that Woodworth in his interesting paper on the fracture system of joints* has called attention to the direction of the fracture lines indicated by the volcanoes off the coast of Asia, and has suggested that the arrangement in crescents may be explained through curved lateral crustal fractures in a system such as he has described in much detail, but in small specimens only. Woodworth's figure to illustrate this structure has been reproduced in Fig. 1. To the present writ-

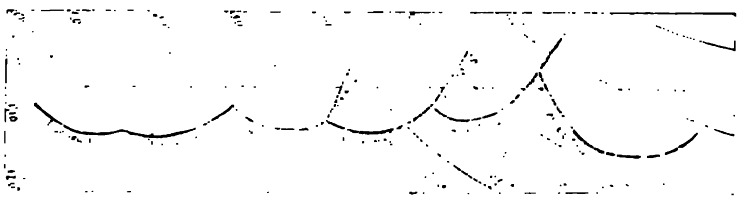

FIG. 1. Fracture Systems of Asian volcanoes.

er it seems better to explain such lines of fracture through the intersection of a number of fault lines in zigzags meeting under the requisite angles.

MANCHURIA.

The structure and geology of Manchuria have been discussed in a recent paper by von Cholnoky describing a journey in that country during the years 1896-'98.† According to v. Cholnoky Manchuria can be looked upon from the orographic standpoint as separated into two parts, one of which lies southeast of the rivers Liau and Songari, the other to the northwest of the same line.

* J. B. WOODWORTH. "On the Fracture System of Joints with Remarks upon Certain Great Fractures." *Proc. Bos. Soc. Nat. Hist.*, vol. xxvii, pp. 163-183.

† EUGEN VON CHOLNOKY. Kurze Zusammenfassung der wissenschaftlichen Ergebnisse meiner Reise in China und in der Mandschurei in den Jahren 1896-98. Verh. d. Gesellsch. f. Erdkunde zu Berlin, vol. xxvi, 1899, pp. 251-61.

Von Cholnoky shows that the Liau peninsula and bay, as well as the western shore of the Yellow sea, are bordered by great normal faults which not only follow the shores, but extend far back into the interior. The line already referred to which borders the high plateau of southern Manchuria continues southward to form the western shore of the Liau peninsula, and crossing the straits of Chili meets the western boundary of the Shantung in China. Where this line of faulting meets the similar lines to the west and east, in one case in the vicinity of Kirin, and in the other on the western border of Shantung, recent volcanic material is found. The eastern one of the series follows the course of the Yalu river. We may here translate to advantage the summary by von Cholnoky referring also to his map which is reproduced in Fig. 2.

FIG 2. Sketch map of Manchuria and surrounding region. Dotted and dashed lines represent faults, full lines show mountain ranges.

"While I am about to present a somewhat clear picture of the structure of the first mentioned district—making my observations supplementary to the studies of Richthofen upon the Liau peninsula—our knowledge of the latter, the northwest district, is still so fragmentary

that the contributions of the Russian investigator Ahnert are the only ones available.

"The peninsula of Liau is according to the studies of Professor v. Richthofen covered by very ancient mountain chains having the direction W.S.W.-E.N.E. These mountain chains are for the most part formed from Korean granite and crystalline schists which are older than the Sinian schists. Upon and between these mountain back-bones the bedded rocks of the Sinian period have been quietly deposited and occur in sufficiently large masses to make it possible to study in detail the age of the beds and the principal mountain systems.

The same can be said of those parts which I traversed. The rocks which I met upon my journey were for the most part massive rocks, the orographic and tectonic studies illuminating also the mountain region at the N.E. of the Liau peninsula.

The road from Kirin toward Mukden follows along the northwestern foot of the plateau of the mountain chain of Kuleh. This so-called mountain chain is really nothing else than the elevated margin of the trap plateau. Here runs a mighty line of fracture having the direction S.W.-N.E. and limiting on the northwest the upland of southern Manchuria. Along this fracture are found numerous volcanoes of youthful age whose nearly uninterrupted continuity lends to the mountain chain its character; of a chain of mountains it is only proper to speak in-so-far as here and there crystalline schists are also found and form individual patches. They lie at a steep inclination and their strike is S.W.-N.E.

"Along the chains of the Thu-Schan as well as on the northwestern slope of the plateau district, basins are found which appear filled out with tertiary deposits. One such we meet in the vicinity of Kirin, where beneath a thick sand and gravel layer lie coal-bearing blue clay slates. A compact brown coal is also found in the same region, which appears to be of ancient origin, whose locality have, however, not yet been visited."

"(1) The mountain chains running in crescents from north Chi-li are terminated in Liau-si by a mighty fracture. This line of fracture appears to meet the second where the greatest number and the most beautiful volcanoes group themselves together in the vicinity of Kirin. On from there—it appears—the line continues to follow the valleys of the Sungari and Amur, even to the northern angle of the island of Sachalin.

(2) On the southeastern side of the Liau river is found a second great fault line; cutting through the region of Kirin and Mukden, it intersects the western border of Shantung. This fracture line was determined by Richthofen.

(3) The third fault line runs along the eastern end of the Tschang-pai range bordering on the east the Liau peninsula and throwing itself forward on the steep side of the projecting peninsula of Shan (Schantung), and uniting with the fault running down from the western side of the Liau peninsula. The point of its junction is character-

ized by strong vulcanism on the southwest point of the Liau peninsula, as it is also by the disturbed condition of the strata. This latter Richthofen's keen eye determined in a manner beyond all doubt. In the case assumed by me, all the mountain ranges in Shantung and in southern Manchuria which without doubt belong to the Sinian system, fall upon one side of this great fault. For this line of faulting in Manchuria it is characteristic that it—as mentioned—is associated with great basins.

(4) The southern part of Manchuria is covered by mountains of the Sinian system which probably extend over from Shantung toward Korea.

(5) Between the two fault lines of Liau-tung is to be recognized in two places the E.W. mountain trend. One is the range of Shang-pai in the south, the other the Thu range and its parallel granite range in the north. Such an east-western mountain range the system of the smaller Khingan also appears to be.

(6) Between the two fault lines of the Liau peninsula and the equatorial mountain chains rises the trap plateau of Manchuria.

(7) Liau si is an abrasion plateau whose main skeleton is formed by mountain chains, which unite in the Tschang-pai. Originally, however, they followed the S.W.-N.E. direction, and terminate on the fault of the Liau-si."

KOREA.

The peninsula of Korea, which Griffis has aptly termed the "land of the hermit nation" has been given a thorough study by the well known Japanese savant Koto.* Under great difficulties he has crossed and recrossed this little known country in a series of geological sections which in most districts are separated by intervals of a little more than fifteen miles.

As a result of this investigation Koto finds that folding, while easily recognized, has been entirely subordinate to a system of faults in producing the positions and attitudes of rock masses, and in determining the present topographic relief. A sketch map showing the location of faults and of axes of folds has been reduced from Koto's larger geological map (Fig. 3).

"The fundamental features of the topography of Korea, as in other lands, are the result of internal geologic structure. Indeed the peninsula was the battle-ground of earth-movements of two directions—the Sinian and the Liau-tung. In the south of the last-drowned rift-valley of Chyuk-ka-ryong, the axes of crustfolds are mainly N.N.E.-S.S.W., i.e. the Sinian. In the extreme north (in the Kai-ma plateau), the fold-mountains run from W.S.W. to E.N.E., in the Liau-tung direction. The

* Bundjiro Koto, Ph. D. "An Orographic Sketch of Korea," *Journal of the College of Science*, Imperial University of Tokyo, Japan. Vol. xix, 1903, pp. 1-61., Plates I—IV.

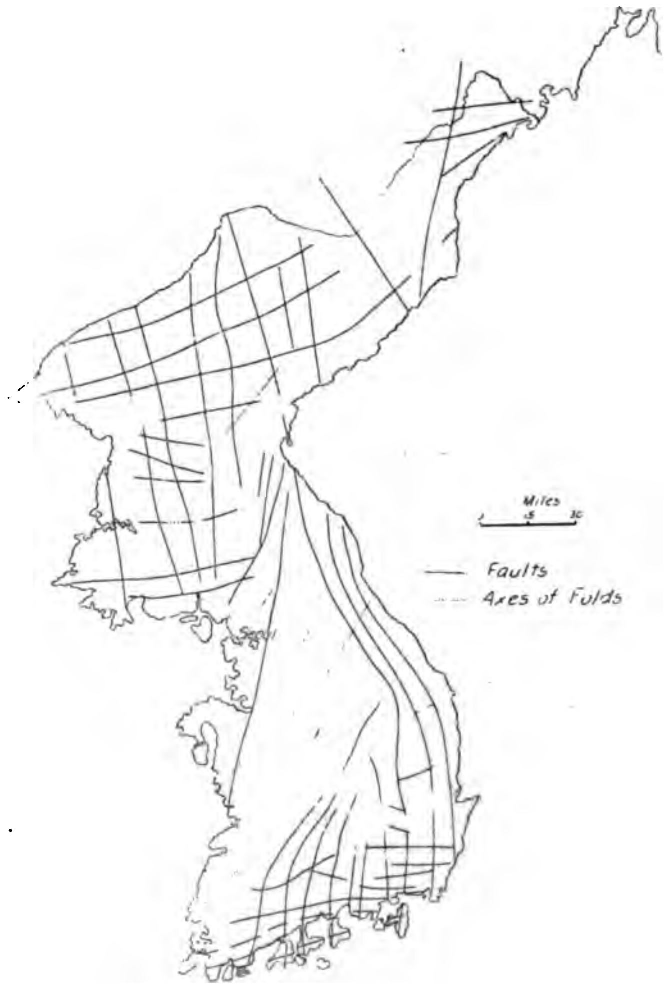

FIG. 3. Sketch map of the Peninsula of Korea showing the distribution of faults and of axes of folds.

earth-movements had folded the core of gneiss-granite together with the overlying mantle of normal gneiss and mica-schist. The kernel of south Korea is the wedge-shaped massive of Chi-ri-san at the boundary of Chyol-la Do and Kyong-syang Do. That of the north is also the wedge-shaped massive of Kai-ma Land. These Sinian and Liau-tung massives, together with their overlying mantles meet each other with their apices, and struggle for the supremacy in north-eastern Ham-gyong Do, thus leaving between them the third wedge of low neutral land.

"Therefore, the peninsula is divisible orographically into three gigantic wedges. The south, embracing the whole of South Korea, is the old land of The Three Hans. North Korea is again divided into the Kai-ma plateau, and the intersertal wedge,—the land of old Chyo-syon or Paleo-Chyo-syon.

I have still to mention a *third element.* This time the earth movement did not produce folds, but ruptured and dislodged the crust, tilting up the edge. The main edge runs N.N.W. to S.S.E., at the margin of the sea of Japan, facing its high scarp to the deep shore. This tectonic disturbance, relatively of young age, produced prominent ridges which constitute the backbone and determine the present topography. The outline of the peninsula is due in a great measure to this geological event. The block-edges I call collectively the Korean range." (pp. 12 & 13.)

"Putting aside the Kai-ma land as an exception, Korea is not a very high mountainous country, nevertheless we find mountains everywhere. It is topographically speaking a labyrinth, and one will find orientation very difficult in the country without the help of good maps. The general disposition of the land is like a checkerboard; this being due to the crossing of mountain-directions. *I have already enumerated about 10 ridges of the Korean System, all running more or less north-south, terminating in headlands, peninsulas and islands in the Southern Archipelago.*" (pp. 26.)

"I have grouped together all these fault-scarps and ridges under the Han-san range, by which the peninsular block has been successively dislodged southward, thus limiting the south border of Korea. Small peninsulas, head-lands, islands, islets and rocks are only the detached masses and fragments with skeletal ridges of the Thai-Paik-san and Han-san ranges. Hundreds of these fragments abound in the south Korean archipelago. (pp. 30.)

"The earth-movements that disturbed and uplifted the Kai-ma land are mainly dislocations and not folds; consequently the disturbance should be classed in the same category as that which created the Korean and Han-san systems. *I can without difficulty distinguish three ridges which run parallel to one another in the Liau-tung direction and constitute the skeleton of this northern plateau.* The two southernmost of these have the steep side towards the *south*, but it is remarkable that they become successively higher at the tilted edge, where the block is suddenly cut off to a lower level on the south. The tilted edge of this narrow but gigantic block is, as I have already stated, the land-mark of the two halves of north Korea. The third parallel ridge, however, falls away steeply to the *northwest;* in consequence of which a comparatively low basin is formed in the drainage-area of the Am-nok and the Tuman rivers, which is limited on the north by the long Chyang-paik-san." (p. 33.)

"When speaking of the surface configuration of south Korea, I have said that it is like a checker-board, and the same feature is not wanting in the Kai-ma Land— (p. 40).

"The peninsula is divisible on good grounds into two sections—north and south Korea—by a trench, in the geological sense, from the head of Gen-san harbour to Kang-hoa bay, at one corner of which is located Che-mul-pho, the emporium and entrance to the capital, Seoul. This trench or rift-valley is lava-drowned and is the only extensive volcanic field in south Korea, except the large basaltic island of Chyorjyu (Quelpart) off the southern coast of Chyol-la Do. This rift-valley or *Graben* of Chyuk-ka-rong (510 m.) affords the easiest passage obliquely across the peninsula from the sea of Japan to the Yellow sea, and marks the boundary of various geographic elements:" (p. 52).

"It is a *rift valley* or *Graben* obliquely crossing the geological strike. From the top of Nam-san in Seoul, we see on the east a regular cliff with its escarpment toward us. It runs from the mouth of the Keum Gang to the head of Wön-san harbour, and the well-fortified castle of Koang-jyu, 12 kilometers from the capital, stands on its edge. I *call this the Koang-jyu ridge.* The *other* ridge starts from the Ma-sing-nyöng, the highest pass of 1020 meters (the second pass A-ho-by-nyong being 760 meters, between Wön-san and Phyong-yang, and lowers at the mouth of he Imjin Gang. The Ma-sing-nyöng ridge turns its fault-scarp to the east, making the counterpart of the Koang-jyu ridge, thus forming the trench-fault. Great basalt flows occurred at the end of the Tertiary, filling up the bottom and now forming the sterile plain of Thyöunon or iron plain, so named from some resemblance of the lava to magnetite. The Chyuk-ka-ryöng road goes gradually up this lava-field, frequently crossing the canyon-like river-channel, and suddenly descends to Wön-san at the above-named pass, which is the edge of the basalt-mesa and the boundary of two provinces." (pp. 9-10.)

"North Korea, as I have already stated, is divisible into two regions, viz., the plateau of Kai-ma on the north, and the hilly land of Paleo-Chyo-syon on the south. The boundary between the two is sharply marked. The north is a *high plateau* with a fault-scarp, facing southwards towards the depressed land, just as the Great Khingan (Hsing-an) turns to the east with its precipice towards Manchuria. The incurves of Korea bay on the west and that of Chyo-syön bay (Broughton bay) on the opposite side give some idea of the boundary as expressed in coastlines, and we can trace it in the interior as well." (pp. 31.)

"Five components of the Thai-Paik-san are the cliffs of tilted blocks sweeping along the coast of the sea of Japan, from which the right wing was successively thrown down to the sea bottom, as if it originated in disjunctive faults as an after-effect of the piling and pressing up of Hondo (Japan) toward the Pacific ocean." (pp. 56-57.)

"The Han-san range resulted from a later geologic event than that which produced the Korean system. The former is composed of a number of tilted edges of faults which threw down block after block to the Southern sea. The sea-coast is dotted with an innumerable number of islets and rocks, and describes complicated in-and-out-curves. These peculiar features which characterize the coast, are nothing more

than the outcome of the joint-work of the orogenic movements that gave form to the Korean and the Han-san ranges. The inlets are the remains of tectonic valleys, while the headlands represent the ridges. Especially remarkable is the narrow canal of the free port, Masan-pho, which presents the outline of a compound cross with a single axis, due to the Korean and Han-san ridges which intersect each other on both sides of the entrance." (pp. 57 and 58.)

"A great number of small ridges or fault-scarps traverse like a gridiron the whole of Paleo-Chyo-syön. The region is somewhat similar in its geological structure to the western half of Shan-tung. Well-established rules can be scarcely discovered in the arrangement of ridges. The whole tract is broken up into a number of long orographic blocks, each being of old sedimentaries, mainly of grey tabular limestone. Each block is tilted along the long side with steep walls, while it slants gradually towards the opposite direction. Some of the *equatorial* ridges may be brought into connection with the tectonic line of Shantung, e.g., Myör-ak-san of Hoang-hai Do, while others of the same group are difficult to correlate with any known system. *Meridional* ridges, though coinciding in direction with some of the Korean system, do not harmonize with each other in position, nor in magnitude of disturbance; the general plan of the west coast, however, seems to have been greatly influenced by them.

In short, the intersecting fault-scarps of Paleo-Chyo-syön inserted between the Sinian and Liau-tung systems seem to be the result of a passive movement and after-effect of the still greater tectonic disturbances which gave to the crust-block of the Korean peninsula its present form." (pp. 58 and 59.)

OUTER GLACIAL DRIFT IN THE DAKOTAS, MONTANA, IDAHO, AND WASHINGTON.

By WARREN UPHAM, St. Paul, Minn.

The outermost boundary of the glacial drift across the entire northern part of the United States, from the Atlantic to the Pacific, was first fully mapped in a somewhat detailed manner by Chamberlin in 1888; though during the preceding twenty years the eastern half of this boundary had become known, with increasing accuracy and definiteness, from the work of many observers, mapping it between the New England islands and the Mississippi river. Comparing Newberry's map of the margin of the drift area,* as it was imperfectly known

* Map showing Drift Area and Bearings of Glacial Furrows, *Report of the Geological Survey of Ohio*, vol. ii, 1874, at page 76 of the chapter on Surface Geology (pp. 1-80.)

thirty years ago, drawn from the Delaware river at Trenton, N. J., to the lower part of the Kansas or Kaw river, with the maps of it published by Chamberlin in 1883 and 1888,* the former reaching westward to the east edge of Montana, but largely revised and corrected for all the country northwest of the Kaw river by his next map five years later, we are greatly impressed with the rapid progress of our American explorations of the limits of glaciation, which were traced exactly or approximately through the distance of more than 3,000 miles across the continent between thirty and fifteen years ago.

A principal incentive to that work was the recognition of the terminal moraines of our continental ice-sheet, in the years 1877 to 1880, by Cook and Smock in New Jersey; by the present writer on Long Island, Block island, Martha's Vineyard, Nantucket, and Cape Cod; by Lewis and Wright in Pennsylvania and Ohio; by Chamberlin in Wisconsin; and by N. H. Winchell and the writer in Minnesota, Iowa, and South and North Dakota. Within three years after the first mapping of the marginal moraines in New Jersey, they had been mapped more or less exactly for 2,000 miles from southeastern Massachusetts to where their course passes out of the United States, from North Dakota into Manitoba and Assiniboia.

About a quarter of a century has since passed, and very detailed surveys of the glacial drift and its extreme margin, and of the many parallel and interlocking or overlapping moraines which limit the areas of the ice-sheet at successive stages of its recession, interrupted here and there by re-advances, have been made by numerous observers in southern New England and Long Island; by Salisbury in New Jersey; Wright and Leverett in Ohio, Indiana, and Illinois; Chamberlin and Salisbury in Wisconsin; Calvin and Winchell and their associates on the geological surveys of Iowa and Minnesota; and Todd and the present writer in the Dakotas.

Farther westward little thorough work has been yet done, though important reconnaissances, and detailed studies in

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* Five maps in Preliminary Paper on the Terminal Moraine of the Second Glacial Epoch, (pp. 291-402), *Third Annual Report of the U. S. Geol. Survey*, for 1881-2, pub. 1883. Map of the Glacial Striæ of the eastern United States (and of the Earlier and Later Drift across all the northern states), in The Rock-Scorings of the Great Ice Invasions (pp. 147-248), *Seventh Annual Report, U. S. G. S.*, for 1885-86, pub. 1888.

some localities, have been made, by Chamberlin and Salisbury in central Montana; by Culver on the front range of the Rocky mountains in the north edge of that state; by Weed in the vicinity of Fort Benton; and by Chamberlin, Willis, Russell, and others, in Idaho and Washington.

There yet remains, however, to be applied to all that western half or two-fifths of our continental drift border, from western North Dakota and the lower Yellowstone river to Puget sound and the Olympian mountains in Washington, the painstaking differentiation of the successive stages of the Glacial period, and precise mapping of any marginal moraines that may be found, such as have been very carefully and instructively worked out in the northern central states of the Mississippi basin, from Ohio to Iowa and Minnesota, noting there a dozen or more moraine-forming stages in the departure of the ice-sheet.

Broadly viewed, the most noteworthy feature of the western half of the continental drift sheet is its less extent southward than that of its eastern half, from Kansas to the Atlantic coast. The rather arid climate of the Great Plains from the lower Missouri river to the Rocky mountains, and likewise of the wide Cordilleran belt until we come to the narrow tract between the Cascade range and the Pacific, had the effect to limit the glaciation in Montana and westward to latitudes averaging about eight degrees, or 550 miles, north of the average limit from Kansas eastward.

In the central part of the continent, for the distance of about 1,600 miles, from southwestern Ohio to the upper Missouri river and its tributaries, Maria's, Teton, and Sun rivers, in northern Montana, reaching nearly to the base of the Rocky mountains on the international boundary, the border of the glacial drift belongs to earlier stages of the Ice age than either east or west. Through that central region, the outermost drift, referred to the Albertan, Kansan Illinoian, and Iowan stages of the long Glacial period, has generally an attenuated edge, destitute of morainic knolls, hills, and ridges, such as extend in narrow belts along the boundaries of the late Wisconsin drift, and which also, in a numerous series of these morainic belts, traverse the areas of that later drift, marking pauses or slight re-advances during the general retreat of

the ice-sheet when it was being finally melted away. East from the Scioto river in Ohio, and westward from the upper Missouri across the great Cordilleran region, the later drift and its moraines reach generally quite to the margin of glaciation, covering the older drift of the previous stages.

One of these stages, named the Iowan, has been shown by McGee in northeastern Iowa, and elsewhere by Leverett and many other observers, to have been characterized by extensive deposition of loess, a fine silt washed down from the dissolving and waning icefields, and deposited by the flooded streams in front of the Iowan drift boundaries, with much redistribution at the same time and later upon large tracts by winds. The loess evidently belongs to a time of general depression of the land beneath the long continued weight of the ice-sheet; and this change, from a former high elevation to mostly lower altitudes than now, appears to have brought again the warm temperate climate under which the continental ice-sheet from then onward was somewhat rapidly melted away, meanwhile forming many marginal moraines at lines of slackening, halt, or temporary readvance, in its general retreat.

On the plains bordering the upper Missouri river in the neighborhood of Fort Benton, and thence northward, loess, or a loesslike fine silt, is described by Weed as spread very extensively, varying from a few feet to a hundred feet in thickness, mantling the nearly flat country, and forming the upper part of the drift there.* Much further exploration is desirable for all the upper Missouri region, to discriminate and map the respective areas of the Albertan, Kansan, and Iowan drift, and to trace the limits of the Wisconsin drift, lying farther north, with its moraines, in Assiniboia and Alberta, to the Rocky mountains.

The oldest glacial drift sheet yet recognized, the Albertan, was so named by Dr. George M. Dawson from its occurrence on the upper edge of the plains of Alberta, along the east base of the mountains, and westward among the Rocky mountain ranges, whence its materials are wholly derived.† The Albertan till and associated Saskatchewan gravels have therefore

* Fort Benton Folio, No. 55, *Geologic Atlas of the United States*, 1899.

† *Journal of Geology*, vol. iii, pp. 507-511, July-August, 1895; *Bulletin, Geol Soc. of America*, vol. vii, pp. 31-66, Nov., 1895.

strictly no extension in Montana east of the mountains and their immediate vicinity; yet probably correlative and contemponaneous till exists beneath the later Kansan, Illinoian, Iowan and Wisconsin drift in the Mississippi basin, where these divisions of the glacial series have been so fully studied and classified in their stratigraphic and chronologic relations by Chamberlin, Calvin, Leverett, and others. Eastern glaciation and drift, which overspread that region, failed to extend into confluence with the Cordilleran glaciation south of the forty-ninth parallel; but north of that line the icefields flowing from the east and west were confluent, with intermingling of their drift deposits on a tract of considerable width extending from south to north not far east of the mountains. In western Montana, and onward to the Pacific coast, the earliest and lowest glacial drift must be correlative with the Albertan of Dr. Dawson, which he regarded as earlier than the Kansan drift sheet, the lowest and oldest recognized previously in the United States.

Including the chief moraine belts, of Wisconsin age, traceable north of the international boundary, it is probable that the northwestern part of the Great Plains, on the upper Missouri river and northward in the Dominion of Canada, has as good a representation of the entire sequence of our glacial deposits, from the oncoming to the final wane of the prolonged and varied Ice age, as can be found anywhere, not excepting Kansas, Iowa, and Illinois, in which states the series has been most elaborately studied and named.

A general survey of our marginal drift formations, from the area of the glacial lake Agassiz west to the Rocky mountains and the Pacific, noting the relationships of the diverse courses of the glacial currents and the relative ages of their drift, convinces me that the view of Tyrrell,* indicating successive culminations of ice accumulation, first in the Cordilleran region, next on the country between the Rocky mountains and Hudson bay, with extension south into Kansas, and last on the Laurentide region, stretching an ice-sheet from Labrador to the Red river valley, is erroneous. Instead of successive Cordilleran, Keewatin, and Laurentide or Labradorian ice-

* *Journal of Geology*, vol. iv, pp. 811-815, Oct.-Nov., 1896; vol. v, pp. 78-81, Jan.-Feb., 1897; vol. vi, pp. 147-160, Feb.-March, 1898.

sheets, there seems to me to have been contemporaneous and long continued glaciation of the entire width of the continent; but during the original growth of the vast sheet of snow and ice covering half of North America, and again during its decline and disappearance, it doubtless outflowed predominantly from those three central areas.*

As the glacial drift generally extends somewhat beyond the Missouri river, to a maximum distance of about fifty miles, through the Dakotas and Montana (excepting a large part of South Dakota, to be again noticed), up to Great Falls, whence the drift boundary passes across this river and runs northwestward to the St. Mary's river and the Canadian line at the base of the mountains, it is evident that during the culmination of the Glacial period, in its Kansan stage, all the rivers of these states, and also of Nebraska, were turned aside to the west and south, being caused to send their waters southeastward along the border of the ice-sheet. In the Fort Benton folio of the Geologic Atlas of the United States, an ancient channel, called the Shonkin sag, eroded by the waters thus pouring along the ice border, has been traced by Weed about fifty miles, passing across the low watersheds. He describes it as "a continuous depression that is clearly an old river channel, with wide valley floor and steep walls and precipitous cliffs." It wil be a most interesting task for amateur geologists of this region to trace these old watercourses, interrupted here and there by beds of lakes that adjoined the ice front, from the vicinity of Great Falls for 1,100 miles east and south, across the Musselshell, Yellowstone, Little Missouri, Cheyenne, White, Niobrara, Platte, and Kaw rivers, to the Osage valley in Missouri, which doubtless for some time carried all the drainage of the Missouri basin, when the present pathway of the Missouri river was thus buried under the edge of the continental glacier. But my last preceding paper (pages 80-87 of this volume) has somewhat fully considered the relation of this majestic river to the glaciation, leaving now a river system probably very unlike its preglacial condition, so that further comment on its changes and development during the Ice age will not be expected here.

* See Maps of the Glaciation of North America, by CHAMBERLIN in Geikie's Great Ice Age, third ed., 1894, pl. xiv, at page 724; by the present writer, *U. S. Geol. Survey, Mon XXV*, The Glacial Lake Agassiz, 1895, pls. ii and xvi; by LEVERETT, *U. S. Geol. Survey, Mon. XXXVIII*, The Illinois Glacial Lobe, 1899, pl. i; and by RUSSELL, North America, 1904, pl. v, at page 315.

Professor G. E. Culver, exploring the front range of the Rockies in northern Montana, found that ice was accumulated so thickly west of the main eastern range, within thirty miles southward from the forty-ninth parallel, that it outflowed eastward through the passes, carrying dioryte boulders from ledges west of the watershed to a distance of several miles on the plains at the eastern base of the mountains. No Laurentide or eastern drift was observed there, but in the valley at the head of St. Mary's river, a tributary of the Belly river, flowing northeastward into Alberta, on latitude 113° 30', five to twenty miles south of the international boundary, he noted shore lines of a glacial lake, which was probably formed by the neighboring barrier of the Laurentide ice-sheet on the northeast. These old shore lines occur up to the hight of at least 800 feet above the present St. Mary's lakes, or approximately 5,400 feet above the sea.*

The Altamont, Gary, Antelope, Kiester, Elysian, Waconia, and later moraines, which have been traced in concentrically lobate courses through South and North Dakota,† were quite surely formed at exactly or approximately the same time with the terminal moraines, outermost and recessional, which cross Ohio, southwestern New York, Pennsylvania, New Jersey, Long Island, and southern New England. Throughout that eastern part of their extent, the outer moraine is at or near the extreme boundary of the glacial drift. In all the interior region, however, from Ohio to the Rocky mountains, the outermost of this series of moraines lies far back from the drift boundary, excepting on the east side of the Wisconsin driftless area, and again along a considerable distance, about 200 miles, in South Dakota, where the Altamont moraine comes nearly or quite to the Missouri river, while the older glacial drift beyond this moraine is scanty or altogether wanting west of the river.

It also appears very certain, according to the judgment of expert glacialists, that the latest great development of glaciers and piedmont ice-sheets in the western Cordilleran region of the United States, spreading generally farther than in the

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* *Trans., Wisconsin Academy of Science, Arts and Letters*, vol. viii, pp. 187-205, with map; Dec. 30, 1891.

† J. E. Todd. *Proc. A. A. A. S.*, vol. xxxiii, 1884, pp. 381-393; *U. S. Geol. Survey*, Bulletin No. 144, 1896, 69 pages. Warren Upham, *U. S. Geol. Survey, Mon. XXV*, 1895, chapter iv, pp 108-191.

earlier stages of the Ice age, was practically contemporaneous with the remarkable Wisconsin stage of glaciation. Although in the central part of the continent the prominent moraines of that stage are far back from the drift border, belonging thus to icefields much restricted from their former area, it is seen that on each side, eastward and westward, the snow and ice were then more abundantly accumulated than ever before, overriding the older drift deposits and encroaching on ground not previously glaciated. When the local causes of the comparatively late maximum growth of the eastern and western parts of the vast continental ice-sheet shall be satisfactorily determined, consistent with the restriction at the same stage in the interior country, it will be a long stride of progress toward fully solving a difficult and most interesting problem, the general causes of the Ice age.

Because of the great extent, both in length and width, of the groups of high Cordilleran ranges, they presented very favorable gathering grounds for glaciers during the Ice age. In remarkable contrast with the eastern half of our country, where the Appalachian mountain belt appears to have had no local glaciers, nor even any notable effect in deflecting the boundary of the ice-sheet from its direct course through New Jersey and Pennsylvania, the glaciation in the Rocky mountain region and onward to the Pacific was greatly influenced by the mountain masses.

In northwestern Montana, heavy glaciation on a width of 50 to 60 miles, extended along the frontal ranges, and on the upper part of the basin of the Flathead river and lake, to a distance of more than a hundred miles south of the main border of the continental icefields. Again, on the high area of the Yellowstone National Park and its environs, confluent glaciers formed an ice-sheet measuring about 75 by 150 miles; and several tracts of mountain glaciers, from one third to two-thirds as large, are mapped farther south, in Wyoming, Utah, and Colorado. On the great mountain ranges and groups of southwestern Colorado, and on the grand Sierra Nevada of eastern California, abundant ice accumulation and effective glaciation reached to the 37th degree of latitude, about 50 miles farther south than the utmost projection of the Laurentide part of the ice-sheet, in southern Illinois.

Only in northwestern Washington, on the basin of Puget sound, occupying a width of 75 to 150 miles between the Cascade range on the east and the Olympic mountains and the ranges of Vancouver Island on the west, was a projection from the continental icefields of British Columbia able to flow into the United States, while of course the far greater part of the ice even there was formed by snowfall on the adjoining mountains.

So marked dependence of the Cordilleran ice accumulation upon the grand topographic features is a complete proof, as I think, that the icefields of the Puget Sound basin and of the Canadian province on the north were produced chiefly by local snowfall, not by invasion or inflow from the central part of the Cordilleran glaciated area. Similarly, as I also think, the southern marginal parts of the Keewatin and Laurentide icefields grew in depth and areal extent chiefly by snowfall on those outer tracts, within the first 20 or 50 or 100 miles back from the extreme ice boundary, in nearly as large degree as the central and thicker parts of the ice-sheet. Yet some glacial outflow took place from the central areas throughout the maximum stage of glaciation; and there was much peripheral outflow during all the stages of growth, culmination, and decline. With the slow ice motion, the very long duration of the Glacial period can be well appreciated when we bear in mind the glacial transportation of boulders a thousand miles from the east side of James bay to southern Minnesota, and the equally long distance of the outermost glacial drift in southern Russia from the Scandinavian mountains that supplied some of its boulders.

Why the ice-sheets shrank earlier from the flat country of the Mississippi and Missouri basins, and of Russia, than from the more hilly or mountainous regions in both North America and Europe, and why morainic drift hills and ridges were formed on each continent principally during the late and closing Wisconsin stages of the Glacial period, are questions that may be probably answered, for the first, by the flat contour and far inland situation of these countries first permanently uncovered from the ice-fields; and, for the second, by the long continuance of glaciation, whereby the ice became more charged with drift in its lower part, and by the more vigorous glacial

currents near the margin after the epeirogenic depression in the Iowan stage of glaciation restored a warm temperate climate upon the ice border.

In the next paper of this series I wish to present my detailed observations of the drift around the southern part of Puget sound, where the proportion of modified drift, stratified gravel, sand, and fine silt, far exceeds the till deposits.

BOLSON PLAINS AND THE CONDITIONS OF THEIR EXISTENCE.*

BY CHARLES R. KEYES, Socorro, New Mexico.

Bolson plains are the most characteristic features of the Mexican tableland. They are peculiar to the arid regions. They could not exist in the same country in which they now do, under conditions of copious rainfall. While they are among the most novel of physical features and while much has been made of them as forming a distinct type of geographic relief they hardly deserve, from the viewpoint of genetic geography and geology, the attention that has been given them.

Bolsons, as their name signifies (Spanish, a purse), are broad, level valleys, depressed slightly in the center, and bordered by mountains. The writer who introduced the name into American geography thus describes them.

"These plains, or 'basins,' as they are sometimes called, are largely structural in origin. Bolsons are generally floored with loose, unconsolidated sediments derived from the higher peripheral region. Along the margins of these plains are talus hills and fans of bowlders, and other wash-deposits brought down by mountain freshets. The sediments of some of the bolsons may be of lacustral origin.

"It is essential, in both the geographic and the geologic discussion, to bear in mind the distinction between bolson plains and plateau plains. The plateau plains and the mountains are genetically related, the strata composing the one being bent onto or flexing out into the other. The bolson plains,

* Read before the Iowa Academy of Sciences, Iowa City Meeting, April 15, 1904.

on the other hand, are newer and later topographic features, consisting of structural valleys between mountains or plateau plains, which have been partially filled with debris derived from the adjacent eminences. The plateau plains are usually destructional stratum plains. The bolson plains are constructional detritus plains filling old structural troughs."*

It has been recently shown† that the structure of the bolson plain is not nearly so simple as the description just quoted would indicate; that they are not, according to the strict physiographic usage of the term, structural valleys; that the bolson plains are not necessarily any newer and later than some of the plateau plains which overlook them: that the constructional detrital covering is no more important than that of the plateau plain; and that the wash-deposits brought down from the peripheral area are relatively of small importance.

On the other hand, it has been clearly demonstrated that the rockbed surface of the bolson plain, that part beneath the thin detrital covering, is a planation surface, a surface worn out on the bevelled edges of the consolidated and indurated sedimentaries.

The bolson plains of New Mexico, for example, are found only in that part of the region which belongs to the geógraphic subdivision known as the basin region. This includes the southern two-thirds of New Mexico, or the portion lying south of the Rocky mountains, which abruptly terminate 100 miles south of the Colorado line. Southward, from this latitude, the bolson plains occur—long, level strips of plains country, separated from one another by high, but narrow mountain ranges. Far beyond the New Mexican boundaries the same type of physiography prevails nearly so far as the city of Mexico.

The peculiar alternation of narrow mountain ranges and broad plains presents many features which are not easily understood until the country both to the eastward and to the westward is taken into account. In both directions from the central highland the "perse" character of the basin plains is soon lost.

The different plains become confluent and more continuous, and the mountain ranges more disconnected and finally

* HILL: *Top. Atlas U. S.*, folio 3, p. 8. 1900.
† *Amer. Jour. Sci.*, (4), vol. xvi, p. 207, 1903.

isolated altogether. Still beyond, the plain alone persists without notable mountains. This condition continues on the one hand to the gulf of California and on the other to the gulf of Mexico.

At the beginning of Tertiary time the region between the two great gulfs north to the present Colorado line must have been a vast lowland plain, with but faint relief features. A large part of this plain was on the bevelled edges of Cretaceous and older strata as is shown now in its remnants clearly discernible. The Las Vegas plateau, the Llano Estacado, the bolson plains of central New Mexico and some of the less broken plains of eastern Arizona seem to belong genetically together. To the east and west of the vast area thus outlined a broad submarine platform was formed from the sediments derived from the planing off of the central land area. When the general bowing up of the region took place later in Tertiary time the great plain formed was partly a peneplain of destructional land origin and partly a constructional plain of marine origin.

After the period of the main uprising, after the whole surface of the country had attained somewhat more than its present elevation above the sea-level, normal faulting on a vast scale gave rise to numerous monoclinal block mountains, with a trend of north and south. There were numerous halts in the general movement and the Mesozoic and youngest Paleozoic beds here are completely stripped off the mountain summits. Several times the staying process has enabled partial peneplanation to take place. But the mountain blocks have become more and more tilted.

Between Tertiary time and the present, enormous erosion has taken place. The vast plain has been deeply dissected by such old mountain-born streams as the Canadian, Pecos, Rio Grande, and Colorado. The valleys of these water-courses are very wide and deep. On the east the Canadian flows 4000 feet below the level of the old plain. The Pecos perhaps 2500 feet. The Rio Grande about 1500 feet. While the Colorado canyon is a mile deep.

In the Llano Estacado the remnant of the great plain contains 50,000 square miles. The bolson plains are already beginning to give way to erosion agencies. In the valley of the

Rio Grande nearly all traces of the old plain are already destroyed. The displaced intermontane basins, like the Jornada del Muerto, which adjoin the long Rio Grande valley, are beginning to be deeply dissected wherever the great river touches the borders.

In its broader features the surface of New Mexico may be regarded as a ribbed tableland. Broad north and south valleys alternate with long narrow more or less continuous mountain ridges. The most important of the long basin plains and valleys are the Pecos, Huerco, Estancia, Jornada, Rio Grande, San Augustine, and Mimbres.

Over such a surface from the southern end of the Rockies three great streams diverge. These are the Canadian river, the Rio Pecos, and the Rio Grande. The first of these after leaving the mountains flows eastward to the Arkansas in Indian Territory and thence its waters find their way to the Mississippi. Rio Pecos trends southeastwardly, entering Texas near the southeast corner of New Mexico. From the San Luis valley in Colorado the Rio Grande flows slightly west of south to El Paso. Of these the last two streams mentioned flow in broad valleys between lines of block mountains.

Comparison of the physiographic features of basin valleys which the great mountain-born streams traverse with those which are not so occupied, quickly demonstrates that the bolson owes its existence merely to lack of erosion agencies. The Rio Grande no doubt at first passed through a series of bolsons identical with those at present found on either side of its present valley. It has cut down its channel often 2000 feet below the surface of the ancient bolsons. Within the valley nearly all traces of the bolson characters are now lost. No waters are received by the great stream after it emerges from the Rockies. The work of this river has been confined to cutting its canyon. Little additional work of side streams has been imposed upon it. A still grander example of its kind is found in the Colorado river of the West. Its great valley, so far below the level of the tableland, exists merely because its drainage-way has its source in a region of abundant moisture.

Between the Rio Pecos and Rio Grande valleys at the south end of the Rockies there is a small mountain stream, the Rio Galisteo, which crosses the Estancia bolson, and which soon

falls into the Rio Grande. This little stream has carved out a remarkable valley. It is an illustration of how wonderfully effective is even a small, often dry, rivulet in corrading the high plains.

The bolson plains may be considered as sections of an upraised peneplain surface in its earliest infancy, at a stage in which they are as yet untouched by stream-action. They could not exist under present hypsometric conditions except in an arid region, which snow-fed perennial rivers do not traverse. The bolsons are only apparently lake-like basins. They have a marked slope in at least one direction, that of their major axis, as in the case of the Jornada del Muerto, where the slant is 20 feet to the mile and greater than the gradient of the parallel Rio Grande. Had the latter stream entered at Santa Fe the Estancia-Huerco or Estancia-Jornanda line of bolsons instead of the line to the westward, a vast canyon would have occupied these basins.

The bolson plains of central New Mexico hang high above the great channels of the Rio Pecos and Rio Grande on either side. Were the rainfall of the region sufficient to produce perennial streams these plains would be soon as deeply carved out as the great adjoining valleys of the rivers just mentioned.

New Mexico School of Mines, July 1, 1904.

THE ALKALI DEPOSITS OF WYOMING.

By Thos. T. Read, Laramie, Wyoming.

Scattered over the south central part of Wyoming are numerous undrained depressions containing large amounts of salts of sodium and magnesium, chiefly sulphates, which are locally known as soda lakes. Of these there are eight groups composed of from one to several lakes varying from a few to several hundred acres in extent. In addition there are smaller lakes scattered in such profusion that no estimate of their number has ever been made.

Two questions chiefly concern us, their origin and their uses. As to the latter, their great future value for the production of carbonate of soda and caustic soda is evident. Many

of the lakes yield pure mirabilite, which upon simple exposure to the air loses its water and becomes anhydrous sodium sulphate. However, the distance of the region from the consumers of sodium sulphate and the consequent high freight tariff has so far prevented their exploitation.

The question as to their origin cannot be so easily disposed of. Of the various theories which have been propounded two alone seem to deserve consideration. Of these the first is that they are the result of the evaporation of the waters of uprising springs which are charged with the alkaline salts. The second is that they have resulted from the leaching of the surrounding Mesozoic rocks. Let us first consider the latter.

Assuming for the moment that these rocks are capable of supplying the amount of salts which we find in the depressions, let us investigate the conditions under which such deposits might be thus produced. In order to have a concrete case let us take the Union Pacific soda lakes which are situated about 13 miles southwest of Laramie in Albany county. We have here four lakes with a total area of about sixty acres. The deposit of soda was reported to be fifteen feet thick in the deepest part of the depression and was assuredly not less than ten feet thick. Allowing for the thinning out at the edges it is safe to assume an average thickness over the entire area of two and a half feet. Upon this basis of computation we find that there are 300,000 tons of the deposit. From the analysis of an average sample of this deposit published by Pemberton and Tucker in the *Chemical News*, vol. 68, p. 19, we find that it consists of 34.85% of sodium sulphate, 1.16% of sodium chloride, 1.45% of calcium sulphate and 0.97% of magnesium sulphate, or a total of 38.43% of alkaline salts; and on this basis we have 115,290 tons of these salts in the deposit.

The surrounding strata are Ft. Benton, and it is reasonable to assume that the percolating waters from whose evaporation the deposits are supposed to have resulted would have approximately the composition of the water obtained from driven wells sunk in these strata. We find that on the average such water contains a total of 50 grains per gallon of the above salts. The records of the Wyoming Agricultural Experiment Station show that the average yearly evaporation from a free water surface is 40 inches. Therefore from an area of 60 acres

we would have 64,686,600 gallons exaporated yearly, leaving a solid residue of 231 tons. At this rate it would require 500 years to create these deposits, assuming that evaporation takes place continuously and that none of the salts are removed. As a matter of fact the lakes are entirely dry during a good portion of the summer, when the evaporation is the greatest, and the milabilite then effervesces to a pulveulent mass which the prevailing west wind carries away in clouds. Probably not less than 2000 years would be required for the formation of these deposits under the conditions we have assumed. No records have been kept as to whether there have been any apparent changes in the extent of any of these deposits, and in the case of the one we have been considering the escape of seepage water from an irrigation canal which now passes just above the lake has caused the re-solution of all the salts, so that it now is a lake of brine and bids fair to remain so. However, I believe all observers of these deposits will agree with the statement that there seems to be no reason to believe that any of these deposits are accumulating at a rate much faster than that worked out above. Therefore we arrive at the conclusion that the vaporation of dilute solutions is sufficient to have caused these deposits and the assumption of uprising waters highly charged with these salts is not only unnecessary, but does not meet the conditions. Taking the deposits in general, the errors in the assumption in regard to the amount of water supplied and the strength of the solution would tend to counterbalance each other.

The next point to be considered is the method of the concentration. This may come from the seeping of the waters through the strata, finally emerging in the basin where they evaporate. Or the subsurface waters, evaporating over the entire drainage area, of which the basin is the lowest part, deposit their load of salts on the surface. At the time of the spring rains the surface waters dissolve these salts and carry them into the basin to be later deposited by evaporation. Both methods find the salts in the strata in which the deposits occur. In the former, however, only the salts lying above the "lake" level could be brought in and in a comparatively short period the supply would be exhausted and no further deposition take place. In the latter, however, the salts might be brought up

from unknown depths below by osmotic action and the volume of strata from which the supply may be derived might thus be immensely increased. That the latter is the more probable source would seem to be indicated by the fact that shallow wells sunk near some of the deposits have yielded water that is fairly palatable, and also the results of the work of the Experiment Station upon hydrography in the area go to show that seepage from precipitated moisture is very small in amount. We now see how the amount of water supplied and the strength of solution are counterbalancing, for the amount of salts brought to the surface yearly is constant and all would be carried into the basin, irrespective of whether the precipitation was great or small.

In the latter case the computation should rather be based on the area of the drainage basin, the average yearly evaporation from the soil, and the strength of the subsurface solutions. So many unknown quantities are here involved that such a computation is impossible with our present knowledge, so that we shall have to allow the original computation to stand, with due allowance for its errors of assumption.

In regard to the theory of the origin of these deposits from springs, certain conditions are obvious. The water must carry only small amounts of salts, or else much larger deposits must have been formed. Springs highly charged with salts, even though they did not break out into undrained depressions which might serve as evaporating basins, would necessarily have produced small deposits. We have no instances of deposits except in these depressions, and it is of course absurd to assume that such springs would break out in such depressions alone. We have no record of any spring in the state which carries more than 150 grains to the gallon of the salts we have been considering.

In the second place, the flow of such springs must be small, or else we would not have the drying up of the deposits in the summer months, which is so characteristic of the greater number of them. There are numerous cases where alkaline lakes do not dry up during the summer months, but in no case is the alkalinity of the waters of these sufficient to justify the assumption of continuous evaporation of an alkaline supply.

Where do the alkaline salts come from? The spring theory has no answer to that question, beyond that they come from beneath.

From a careful consideration of the evidence it would seem that both theories are right, and find their application in different instances. The southern edge of the valley of Rock creek, which that stream has cut in the crest of an anticline, is a ridge of hard Dakota beds. Near the crest of this ridge is an undrained depression containing one of these deposits. We clearly can have no application of the first theory here, for with the exception of a low rim, the surface slopes away from the depression. On the other hand, we have numerous springs breaking out on all sides, all of them of water which is good enough to drink. These springs join into a small stream which flows into Rock creek. This seems clearly to be a case of a spring whose yearly flow is not equal to the yearly evaporation from its lake basin. In the case of the Union Pacific lakes we find a larger and deeper undrained depression, containing no deposit, a few miles to the north and another to the west. The absence of such deposits from these depressions is inexplicable by the theory of the leaching of the surrounding strata, since at least one of these depressions occurs in exactly the same strata. Therefore uprising waters from be neath must again be the probable source.

On the other hand, it seems almost certain that the leaching of salts from the surrounding strata must have at least aided in the formation of the alkaline deposits. The presence of efflorescent crusts of alkali throughout the arid region shows that such salts are brought to the surface and surface drainage would naturally concentrate the alkali in the evaporating basin. Hence we arrive at the conclusion that both causes have operated, their relative importance differing in specific cases.

As to the origin of the salts themselves there is almost no evidence to offer and without good evidence it is useless to construct a hypothesis.

The position taken by Dr. W. C. Knight in Bull. 49 of Wyoming Experiment Station, "Alkali Lakes and Deposits," seems to be clearly untenable. He assumes that the salts have been carried down mechanically by the sediments as they

were deposited, but in such case it is difficult to see why sodium chloride is entirely absent in nearly every instance. The most definite statement that it would seem safe to offer is that they must have been produced during rock decomposition by chemical reactions, the exact cause of which is not known. See the work of Hilgard on alkali in soils.

SUMMARY.

1. Deposits of sodium and magnesium sulphates of great extent exist in south central Wyoming.

2. These deposits offer a valuable source of sodium and its salts.

3. The salts appear to have been in part brought to the surface by uprising waters and in part derived from the leaching of the surrounding strata.

4. The origin of the salts has not yet been satisfactorily explained.

April, 1904, *Department of Geology, University of Wyoming.*

NOTES ON THE PLEISTOCENE FAUNA OF SANKATY HEAD, NANTUCKET, MASS.

By Joseph A. Cushman, Boston, Mass.

The geological events of this interesting locality have been a matter of considerable discussion since they were first definitely treated by Desor and Cabot in 1847. The section exposed has changed somewhat in the ensuing time and only a portion of the original section is now exposed. The details of this are given by Merrill and are reproduced here.

1.	Fine dark drifted sand	3 ft.	
2.	Yellow sandy drift	5 "	
3.	Coarse gray stratified sand, etc	40 "	
4.	Fine white clayey sand, etc	10 "	
5.	Fragment Bed. [4]	1 "	
6.	Upper shell Bed [3]		8 in.
7.	Clayey ferruginous layer		4 "
8.	Serpula sand [2]	1 "	3 "
9.	Lower shell Bed [1]		9 "
10.	Red sand with clay	1 "	
11.	White sand	4 "	
	Concealed	24 "	
	Total	90 ft.	

PLEISTOCENE FAUNA OF SANKATY HEAD, NANTUCKET, MASS.

LIST OF SPECIES.	1. Lower Bed	2. Serpula Bed	3. Upper Bed	4. Fragment Bed	Rang
Porifera.					
Cliona sulphurea Desor	Abundant				S
Echinodermata.					
Strongylocentrotus drobachiensis Mull			Spines only		N
Annelida.					
Serpula dianthus Verrill	Abundant	Abundant			S
Bryzoa.					
Hippothoa variabilis Leidy	Common	Common			S
Membranipora tenuis Desor	Common				S
" catenularia Smitt	Common				N
Eschara verrucosa Esper			On shells		N
Celleporaria incrassata Smitt (?)			Several		N
Mollusca (Pelecypoda).					
Arca pexata Say		x			S
" ponderosa Say	One speci'n				S
" transversa Say	Abundant	x	Few		S
Ostrea virginica Gmel	Abundant	x	Few		S
Anomia aculeata Gmel			Common		N
" simplex d'Orb.	x				S
Mytilus edulis Linn	Few		Common		N
Modiolus hamatus Verrill	Common	x			S
" modiolus Linn			Many	x	N
Crenella glandula Totten	Few		Sever'l, large		N
Thracia truncata Mighels and Adams			Few*		N
Pandora (Clidiophora) gouldiana Dall			One valve		N
Astarte castanea Say		x	Abundant		N
" quadrans Gould		x		x	N
" undata Gould			One valve		N
Gouldia mactracea Linsley	One speci'n				S
Venericardia (Cyclocardia) borealis Conrad			Common		N
Venericardia (Cyclocardia) novangliae Morse			Few	x	N
Venus mercenaria Linn	Abundant	x	Few		S
Var. Antiqua Verrill	Abundant				
Gemma gemma Totten	Few				N. S.
Petricola pholadiformis Linn	Rare				S
Tellina (Angulus) tenera Say	Several				S. N.
Macoma balthica Linn			A few valves		N
Cumingia tellinoides Conrad	Common	x			S
Ensis directus Conrad	Abundant	x	Few		S. N.
Spisula solidissima Dillw			Common	x	N. S.
Mesodesma arctata Conrad			Abundant		N
" deaurata Turton			x*		N (N.)
Mya arenaria Linn	Abundant		Few		N. S.
" truncata "			Several		N
Corbula contracta Say	One valve				S
Saxicava artica Linn	Few		Common		N
" norvegica			One valve		N. (N.)
Panopaea sp.?			Fragments*		S

* Exact bed not given, referred provisionally to this bed by Prof. Verrill or by the writer.

LIST OF SPECIES.	1. Lower Bed	2. Serpula Bed	3. Upper Bed	4. Fragment Bed	Range
***Mollusca** (**Gastropoda.**)*					
:lla obscura Couth				Frag-ments	N
ımia impressa Say	Common				S
trifida Gould	Common	x			S
ıilla interrupta Totten	Several	x			S
grœnlandica Perry			x* (B. S. N. H.)		N
ula convexa Say	Not common	x			S
fornicata Lamk	Abundant	x	Few		S
plana Say	Common		Few		S
ulum striatum Say			1 speci'n (v) (also Merrill)		N
pinx cinerea Say	Common	x	One speci'n		S
ıra caudata Say	One speci'n				S
; lunata Say	One speci'n				S
ı heros Say			Common	x	N. S.
r. triseriata Say			x		N. S.
ita duplicata Say			One speci'n		S
a aculeus Gould				x	N
a planorbis F. & H				x	N
ra noachina Gray			Two spec'ns		N
m pulchellum Stimp				x	S
iopsis greenii C. B. Adams	Four spec'ns				S
ıum undatum Linn			Common		N
trivittata Say	Few		Common		S. N.
(Ilyanassa) obsoleta Say	Few	x	Few	x	S
odomus curta Jeffreys			Several		N
ıon scalariformis Gould		x			N
Crustacea.					
us crenatus Brug	Common				S. N.
eburneus Gould	Common	x			S
porcatus	x		x	x	N.(N.)
gurus pollicaris Say	One speci'n*				S
ɔeus sp	x	x			S

There are, according to his observations, four main fossiliferous beds, marked 1-4 on the section as here given. This division in place of the older idea of two beds gives additional characters from which certain conclusions may be drawn as to the fauna.

It is the aim of the writer to present the data in regard to the fauna of these four beds in a simple manner. Several new species have been added since the publication of professor Verrill's paper in 1875. These additions for the most part substantiate the conclusions drawn by professor Verrill in regard to the faunas of the different beds, that is, the original

* Exact bed not given, referred provisionally to this bed either by Prof. Verrill or by the writer.

conditions under which they were formed before transportation.

From the pocket-like character of the shell deposits as well as other characters of the material in which they are at present found, the idea that they have been transported or at least secondarily worked over by water, must, it seems, be accepted.

The whole fauna as here given consists of 71 species and 2 varieties, ten of these species having been added since professor Verrill's list. Of these Panopaea sp. and Mesodesma deaurata (M. jauresi) were added by Hollick; Caecum pulchellum, Astarte quadrans, Cingula (Rissoa) aculeus, Solariella (Margarita) obscura, Skenea planorbis, Trophon (Fusus) scalariformis, and Arca pexata were added by Merrill, and an excellent specimen of Arca ponderosa was found among the early collection of Mr. Scudder by the writer.

In the last column of the table is given the range of the species either to the north or south. In some cases it is about in the middle point of its range and both letters are given, the one indicating the greater range being given first. In one or two cases the species is not now found living at this point and this fact is indicated in the column by repeating the letter indicating the range in parenthesis, as N. (N.) meaning that the species does not at present range south to this point in shallow water.

Relations of the Fauna of Bed. No. 1.

At the present time there are forty species and varieties which have been identified from this lower bed. The one crustacean Eupagurus pollicaris is hypothetically referred to this bed by professor Verrill. The only specimen was found by Desor. Of the forty forms thirty-two have a decidedly southern range; one other, the var. antiqua described by Verrill, is limited to this locality as far as known. Of the remaining seven forms with a northern range, two have a decided southern range as well, of the remaining five, three species are found rarely in this lower bed and much more commonly in the bed above, the other two remaining species being decidedly northern, one of them only now found at this point in deep water. Therefore 87½% of the forms found in this bed would be found more commonly to the south of this point today,

while all but one species of the others would be found, although near the southern limit of their range.

Relations of Fauna of Bed No. 2.

In this bed the earlier writers mention simply Serpula and its encrusting bryozoan. Merrill found in his work on it sixteen additional species, giving this bed a distinct fauna of its own. The forms found indicate a change in conditions and especially a transition toward the faunal conditions of bed 3. Of these sixteen species, thirteen represent those that were present—in most cases abundant—in the first bed and which either disappeared entirely or were limited to few specimens in the upper bed. They represent the remnants of fauna No. 1 left before the completed change of conditions sent them out entirely.

Of the other three, one, a northern species, has been found only in this bed, the other two represent northern species which make their first appearance here, but are found again in one of the upper beds. Thus the transition character is easily made out, having the last appearance of many of the southern species of the lower bed and the first appearance of northern species of the upper beds.

Relations of the Fauna of Bed No. 3.

From this bed forty forms are now known including four species placed here hypothetically. Of these twenty-six did not appear in the first bed. Of this last number twenty-four have a decidedly northern range. Of the other two, one is referred hypothetically, simply fragments being found, while the other is represented by a single specimen. Those species which were found in the lower bed are represented by very few specimens in almost all cases. The fauna of this bed then represents the completion of the changed conditions and a much more northern fauna due to much cooler water while the earlier, more southern species have either entirely disappeared or are represented by few individuals.

Relations of the Fauna of Bed No. 4.

This bed according to Merrill contains eleven species. Their relations are decidedly northern. Four of these have not been met with in the other beds. Of these, three have decidedly northern ranges, the fourth being almost limited to this gen-

eral locality. Of the other seven, six represent species of northern range not found in the first bed. The other one represents a species found in all the beds. This bed consisting as it does mainly of fragments shows probably far less of its original faunal members than the other beds. From those which it does contain it probably represents a condition not unlike the present except that the southern species were not again established at that point.

Whether the idea of transportation of the material is questioned or not there remains the fact that there are represented by the contained fossils, four distinct stages. All four stages probably represent a period during freedom from the ice sheet somewhere between the earliest and latest advances.

Two species, Arca pexata and Ostrea virginica, were found by Merrill in a bed intermediate between Beds 2 and 3. The list as here given includes all the species and varieties reported from these beds, the names used, being as far as possible, according to latest usage.

LAKE OTERO, AN ANCIENT SALT LAKE BASIN IN SOUTH-EASTERN NEW MEXICO.

By C. L. Herrick, Socorro, New Mexico.

PLATE XI.

To a mind endowed with some imaginative powers one of the attractive features of geological study is the continuous series of panoramic portrayals of earth-building which it spreads before one—pictures which present the grand outlines of continents and seas during the course of profound changes requiring ages for their completion. It is a very apathetic mind that is not stirred by the sheer immensity of many of the geological movements which are plainly evident in the configuration of mountain and plain, especially in the arid region where there has been little glossing over of the rude narrative.

This sense of the immensity of geological manifestations is felt in any mountainous region in the Southwest equally from two points of view. The evidence of profound faulting and dislocation is so clear and convincing as almost to over-

shadow the still greater, if more gradual, work of erosion which has planed away the broken or arching strata, leaving the clear outlines of faulting more plainly in view than in any other region whatever.

Any peak of the San Andres or Sacramento mountains in south-eastern New Mexico may become a veritable Pisgah to the trained observer, though it is history and not prophesy that will occupy him. The writer has briefly described the valley of the "white sands"* but in the present paper we are able to trace historical features not hitherto published.

To one standing upon the foot-hills of the White or Sacramento mountains on the morning of a clear day and looking west there is presented a view which cannot be duplicated elsewhere. At his feet is a nearly level plain crossed from north to south by the El Paso and North Eastern Railway and dotted with a number of villages prominent among which is the new city of Alamogordo, each settlement being picked out by the bright green of the unfailing cottonwoods.

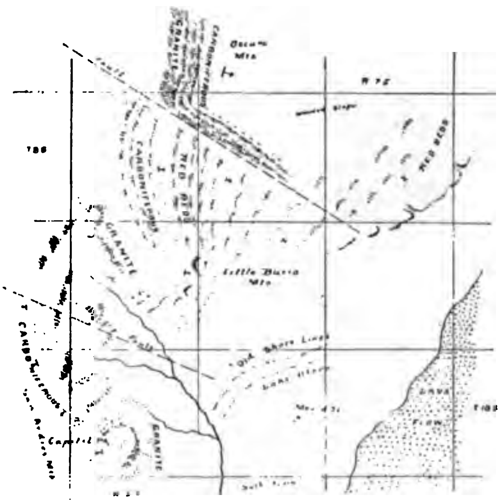
The vivid green of the grease-wood (*Laria*) fades as the plain is followed west. Numerous canons from the foot hills extend as arroyos all converging toward the central portion of the plain where they abruptly disappear Still beyond, covering an area of over 300 square miles, is a great white expanse of gypsum sands whose parallel dunes seem like frozen waves. It is impossible to escape the impression that one is looking out upon a great arm of the sea breaking in foam-like billows upon a low shore. Beyond, grey in the distance, are the outlines of the San Andres, whose irregular crests are capped with Carboniferous limestone dipping west.

A recent opportunity afforded by a survey of this area has permitted the writer to study this plain in considerable detail and not only to secure evidence of the truth of the theory of origin of the "white sands" advanced in the previous paper but also to work out the general outlines of the history of the entire basin.

The origin of the great valley between the San Andres and Sacramento mountains is to be attributed, as previously suggested, to a great anticline similar to that of the Rio Grande valley. This axis is nearly north and south but is not

* *Bull. Univ. New Mex.*, vol. ii, Fasc. 3

continuous in the same straight line to the north, for the Oscuro mountains, which are almost the direct northward continuation of the San Andres, form the other limb of the anticline, dipping east instead of west, there being a region of sharp flexture about a short axis or pivot near the north end of the San Andres, giving rise to the Little Burros mountains.



North end of San Andres Range.

The conditions represented in this little sketch are of sufficient interest to permit a remark. It would appear to the casual observer that the Oscuro and San Andres mountains, separated by the Mocking Bird pass, form part of the same system, but even hurried geological examination reveals the fact that the dip is in opposite senses and that the region of the pass is a part of neither the Oscuro nor the San Andres system but forms a distinct element. When compared with the Oscuros it is faulted so that the base of the Carboniferous, or at least the granite contact which is some 1500 ft. above the plain in the south end of the Oscuros, drops in the Little Burros to, and in some places below, the general level. What is more surprising is the fact that a part of the north end of the San Andres is involved in this Little Burro mass. The fault represented north of Capitol peak has not been studied closely and may not extend through the range as represented. At any rate, the Carboniferous hills of the Little Burro block

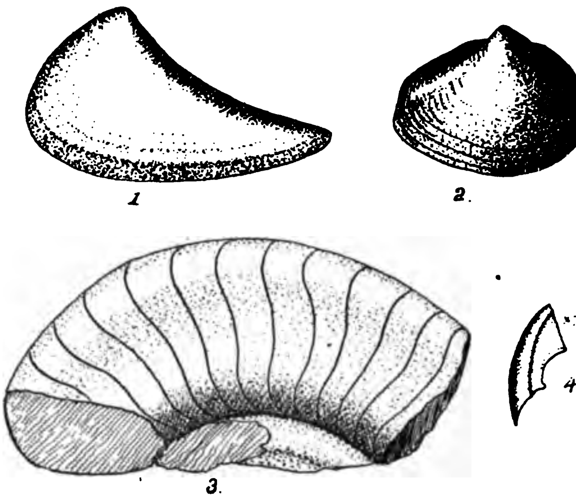
abut against the granite of the north end of the San Andres. The entire northern ridge of that range is bare of stratified rocks. To the south of the fault indicated the dip of the strata is uniformly to the west. The lava flow, part of which is represented, extends for about fifty miles uninterruptedly in the valley east of the Oscuro mountains and ends abruptly on the plain formed by the basin of lake Otero, the upper part of which was covered by it.

In the main, and south of the Little Burro block, the anticline is relatively simple and not unlike that illustrated as typical of "basin range" structure in Russell's article on lake Lahontan (l. c. fig. 44) with which region the present locality is naturally compared. The dip on both sides, in the San Andres and Sacramentos respectively, is moderate and subject to much local variation.

It may be presumed that the orographic flexture creating this axis dates from a period earlier than that of the sedimentaries deposited on the granite which is everywhere their base, for it seems to be true that the lowest sedimentaries on the east (Sacramento) side of the valley are of earlier age than those exposed in the San Andres, or, in other words, the formation was not homogeneous nor was it uniformly deposited across the incipient uplift. This uplift probably exposed the granite during the Carboniferous-Permian interval, if such there was, though the greater part of the granitic material characteristic of the lower Permian may have come from special (focal) uplifts like that forming the foundation for Sierra Blanca north of the Sacramento range.

If we were to assume that the entire Permo-Carboniferous was uninterruptedly laid down before the arch began to be sprung this would mean that a tremendous elevation was at one time reached and a still more enormous erosion would be required, for, granting a thickness of say 3000 feet to the sedimentaries, even a very flat arch would have the effect of carrying the summit to a great hight in the forty miles or so intervening between the buttresses left as the ranges mentioned. But it is certain that the flexture was accompanied by faulting on a large scale. The small ridge forming Cerrito Tularosa east of the "sands," and others farther south but along the same axis, are of dark earthy limestone with fossils

supposed to be of Permian age, and evidently represent the tops of faulted blocks indicating a drop of perhaps 4000 to 5000 feet. Similar conditions are not known to exist on the west side of the valley but the tops of faulted blocks may be buried beneath the sediments.



Four fossils from the Cerrito Tularosa, an outlier of Permian limestone along fault line on the east side of Lake Otero basin.

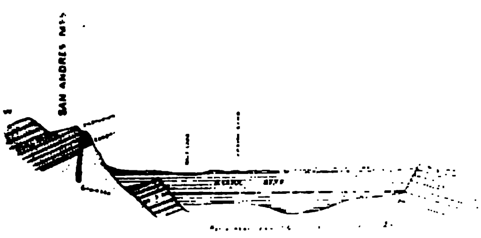
It is clear that the axis of uplift became a drainage axis quite early. To the east the sedimentaries carried to the top valley, where, as I am informed by Dr. W. G. Tight, who has studied the region, they form the water-bearing horizons of that celebrated artesian area. The same may prove to be true of the plains to the west of the San Andres known as the Jourado del Muerto (Journey of Death). Although the fracture axis of our valley may have been early, the latest uplift of the Sierra Blanca was certainly later than the Cretaceous for Mr. H. N. Herrick has collected Fox Hills fossils from well up on the western slope and a curious broken area of Cretaceous intersected by dikes of recent basalt occupies a position at the base near Three Rivers and this block is faulted down to the level of the Permian which borders it.

It may be supposed that the great faults which reduced the valley to something like its present level occurred during late Cretaceous or Tertiary time, though even greater dislocations may have followed the period of the Red Beds, i. e. at

the time of the great early basic (mostly andesitic) flows and the succeeding acid eruptive period.

There is much to lend plausibility to the theory that a river of considerable magnitude occupied the valley and flowed south to enter what is now a part of the Rio Grande valley. At any rate, a change was introduced by the basaltic overflows which produced a great sheet of "mal pais" occupying the valley east of the Oscuros and possibly serving to cut off the superficial waters from the north. It may be that other causes had operated to occlude the original outlet to the south for it seems that a long period of lacustrine quiet had preceded this lava flow. Perhaps the condition of periodic rain-fall or arid status had assisted in silting up the outlet.

There is room for much detailed study in connection with all of these questions. At any rate, it may be regarded as certain that the great basin north of the Jarilla mountains and extending northward to east of the Oscuros was for a very long period covered by a salt lake in which gypsum, salt, and saline alkalis were deposited with intermittent regularity. Thus were formed the great saline beds which we venture to call the *Otero marls.* This formation has been penetrated by wells to a depth of some 200 feet in many places and everywhere reveals a succession of gypsum and saline beds intercalated in gypsiferous marls. It is impossible to guess at the thickness of this formation. It may very possibly prove to be of Tertiary age, at least in part, as it seems to pass undisturbed under the lava beds at the north end of the valley. The upper surface, where exposed, is a plane and the superposed sandy marls (Tularosa Formation) are distinctly differentiated.



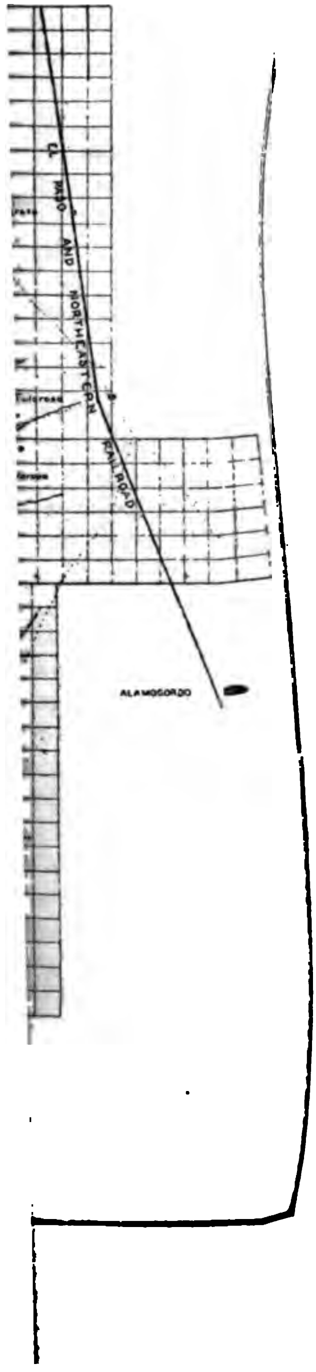
Section across old Lake Otero.

The upper or *Tularosa Beds* are rarely over twenty-five feet thick and in many places contain fresh-water lacustrine

shells. It would appear, therefore, that the line between the upper and lower beds marks a period of transition to a time when more water and more sediments entered the lake from the sides. The lake was divided during this period, probably near its close, into two parts which may have been connected, as now, by a narrow strait. The division is apparent to-day as a bank rising some twenty-five to forty feet above the beds of the residual lakes and is nearly parallel and adjacent to the north boundary of Doña Ana county where it crosses the valley.

The sandy marl of this period is usually quite fine and may be gypsiferous. It has apparently been derived from the Cretaceous sandstone and shale and the soft gypsiferous shales and sandstones of the Permian. This points to the probability that the change from the lower to the upper formation may have been due to the lava flow which penetrated the border of the lake and doubtless laid these formations open to fresh erosion. If these intrusions were of the same age as the flow covering the northern part of the valley the latter may at the same time have served to cut off connection with saline districts to the north.

In the absence of more minute investigation it is useless to speculate as to the entire course of the original river valley but it is obvious that even the present drainage area tributary to the great salt basin is sufficient to supply an enormous amount of water which must either find an underground outlet or return to the atmosphere through evaporation. The amount lost in the latter way is reduced by the fact that the waters tend to bury themselves under the upper or Tularosa formation. A comparatively small part of even the local flood waters remains upon those playas which represent the last remnants of the original lake Otero. The streams flowing from the lateral canons soon lose themselves under the sandy strata occupying the middle of the basin. Water may be found by penetrating the Otero beds at any point and frequently near the top of that formation. All such waters are strongly impregnated with common salt and alkaline salts and with gypsum but different strata in the same well may afford water very dissimilar in point of salinity.


EL PASO AND NORTHEASTERN RAILROAD
Tularosa
ALAMOGORDO

In describing this basin one is forcibly reminded of Mr. I. C. Russell's account of lake Lahontan; in Powell's Third Annual Report; indeed, much of his description of the Great Basin applies, on a reduced scale, it is true, to the region in question. "No streams that rise within it carry their contribution to the ocean, but all the rain that falls inside the rim of the basin is returned again to the atmosphere, either by direct evaporation from the soil, or, after finding its way into some of the lakes that occupy the depressions of the irregular surface. The climate is dry and arid in the extreme." It has been a matter of frequent observation that during the early part of the rainy season clouds from which rain is falling in torrents will pass over such dry reaches of sand intensely heated by the sun and, on reaching their borders, the rain will fail to reach the earth and soon perhaps the cloud will cease to precipitate but may resume its occupation on reaching the farther (cooler) side of the plain.

The mountains bordering the lake basin conform to the "great basin type." "They are long narrow ridges usually bearing north and south, usually steep upon one side, where broken edges of the composing beds are exposed, but sloping on the other with a gentle angle conformable to the dip of the strata. They have been formed by the orographic tilting of blocks that are separated by profound faults, and they do not exhibit the synclinal structure commonly observed in mountains but are monoclinal instead."

To this description it may be remarked that the structure in question is by no means limited to the Great Basin, for throughout a great part of New Mexico this is the type of mountain formed where Carboniferous and earlier strata are involved in the uplift. It is a mistake to suppose that this is essentially a monoclinic type. Anticlines exist on a grand scale but these arches grow coincidentally with vast erosion and faulting and were often greatly altered by later intrusion phenomena which, as I have repeatedly pointed out, commonly chose one of the lateral axes of the anticline for the play of their disturbing forces.

Much as it has been altered by late disturbances and enormous erosion and sedimentation, it is impossible to fail to recognize the anticline of the middle Rio Grande valley, for

instance, yet it is not common to find both sides clearly preserved at any one cross-section. The eastern limb is seen in the Sandias and Manzanos, the western, farther south in the Ladronnes, Limitars and Socorro ranges, while still further south the river turns west but remains in the anticlinal valley, the eastern border of which is formed by the San Cristobal and Caballos ranges. The eastern limb is nearly covered east of Socorro.*

We do not conceive of this great fold (nor that east of it, forming the basin under consideration) as narrow plications but rather as great undulations with irregularities which may in places almost obscure the general north and south trend. The foundation for these orographic changes was laid after the upheaval that closed the granite-forming period, that is prior to the deposition of the Carboniferous (farther south, Devonian) limestones that repose upon the granite. The upper surface of the granite is planed to such an extent that the contact at a distance appears a right line. These sediments, in so far as they are not calcareous and so derived directly from the ocean, seem to have come from the surviving peaks or land masses of granite not covered by the Carboniferous sea and there is every reason to believe that during the Carboniferous-Permian interval (if interval there was) an uplift presented more of the granite material to the tooth of the waves. The unconformities thus indicated seem to have been on a large scale and are so broad in their contours as to defy detection in a small field of observation though when once worked out they may be strikingly obvious. Reverting to our description, we again quote Mr. Russell: "The valleys or plains separating the mountain ranges . . . are often absolute deserts, totally destitute of water, treeless for many days' journey, the grayish green *Artemisia* or "sage brush" giving character to the landscape. Many of them have playas in their lowest depressions—simple mud plains left by the evaporation of former lakes. . . . In the summer months portions of them become so baked and hardened as scarcely to receive an impression from a horse's hoof, and so sun-cracked as to resemble tessellated pavements of cream-colored marble.

* Laws of Formation of New Mexico Mountain Ranges. AMERICAN GEOLOGIST, May, 1904.

Other portions of the valleys become incrusted to the depth of several inches with alkaline salts which rise to the surface as an efflorescence and give the appearance of drifted snow. The dry surface material of the deserts is sometimes blown about by the winds, saturating the air, or is caught up by whirlwinds and carried to a great hight, forming great hollow columns of dust. These swaying and bending columns, often two or three thousand feet high, rising from the plains like pillars of smoke, are a characteristic feature."

The above might almost have been written of the Otero basin, which, nevertheless, has peculiar features of its own. Prominent among these are the great dunes of gypsum sand occupying fully 300 square miles lying immediately east of the largest playas. These "white sands" have no counterpart elsewhere and have frequently been described.* It must not be supposed that the area of the white sands is absolutely barren. On the contrary, it forms the only part of the basin which supports a thrifty growth of vegetation. This consists of occasional clumps of cottonwood trees and clusters of bushes of various species as well as of Artemisia and grasses. There are even small flats covered with Grama grass forming excellent feed. The superiority of the vegetation over other parts of the basin is chiefly to be attributed to the hygroscopic nature of the gypsum. We found, for example, in the midst of a very dry time when the surface of the dunes was so hot that one could with difficulty endure the beat upon the bare hand, that a few inches below the surface there was a layer of damp sand several inches thick. Below this layer the sand was perfectly dry. Even in very hot weather this area is very cool at night and this is the result of precipitation, evaporation and reprecipitation upon the sands. Experiments made at the Agricultural College of Las Cruces show that the gypsum is of value in increasing the growth of wheat and other crops upon soil with which it is mixed. This appears to be wholly due to the hygroscopic action of the gypsum. It is probable that, when properly understood and utilized, this property will be made greatly to benefit agriculture in the arid belt. A sufficient covering or admixture

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* *Cf. Bul. Univ. New. Mex.*, vol. ii.

of gypsum might render soils to some extent immune to droughts.

The dazzling whiteness of the sand is strongly contrasted to the unusual greenness of the vegetation. Travel over the sands in the day time during summer is dangerous and the peril is even greater during severe wind storms in winter. Two travelers perished on the day following the escape of our party on a previous visit in January. Seven hours rapid walking over the sands and adjacent salt flats without food or water in July convinced one of our party of the grave possibilities of any miscalculation of time or distance in this region. These natural difficulties are greatly increased by the undrinkable nature of the water of springs and wells in this region. Animals and even men become innured to its use but vast numbers of domestic animals perish from its effects. We lost a valuable horse from the effects of drinking from a well used by hundreds of animals and the occurrence is not unusual. All watering places are surrounded by carcasses of cattle and horses.

To the residual lakes found in the old basin the description of Russell applies, and as some interest attached to the parallel, we again quote:* "Other lakes, which indicate still more pointedly the contrast between an arid and a humid climate, we may call playa† lakes. These are broad sheets of shallow water, covering many square miles in winter season, but evaporating to dryness during the summer, their beds becoming hard, smooth mud plains or playas. In many instances a lake is formed over a playa during a single stormy night, only to disappear beneath the next noon-day sun."

The effects of the universal whiteness on life is seen in the case of certain lizards, beetles and spiders, which become nearly perfectly white. A question of considerable biological interest arises in this connection, namely, whether a long interval of time was necessary for such adaptive changes, or whether the adaptation occurs as a result of direct and prompt nervous reaction such as the paralysis of the nervous

* *L. c.* p. 198.

† The word *playa* primarily means a shore or beach. It would be interesting to know how it comes to be applied to these mud flats. One is tempted to think of a confusion of terms. C. L. H.

apparatus controlling the chromatophores or the bleaching of the colors themselves. In the case of the lizard, *Holbrookia texana,* which is a rather poor pedestrian, the transformation of the upper parts is nearly complete but the characteristic blue bands remain below in contrast to the original white of the under parts. *Crotophytus colaris,* a very fleet and active species which can, upon occasion, pick up its tail and fore feet and make great progress as a biped, like some of its gigantic forebears in the west, is little if any modified so far as observed.

Extent of Lake Otero.—So far as we can now determine, the area of this ancient lake may have been from 1600 to 1800 square miles. We have made no examination to the south to ascertain if the nature of the barrier can be made out. It may have extended nearly to the Jarillas mountains. From the nature of the case, the old shore lines must be deeply buried under the talus from the mountains whose fans spread out a great mantle of lime debris. Near Alamogordo at the mouth of one of these mountain canons a well was drilled over 800 feet without reaching solid rock. Along the gradual slope west of the southern tongue of mal pàis, i. e. along what was the northwest border of the lake, erosion has exposed what seem to be remnants of old lake benches. At no other place have they been observed though three or four distinct benches border the playas upon the Tularosa formation.

We may assume that the saline lake began in Tertiary time and continued with minor changes to a period of disturbance which may have coincided with the lava flow already mentioned. If the extrusion of so vast an amount of lava caused a sinking of the northern part of the valley, a deepening of the lake would result and a corresponding diminution in extent which might account for a greater depth of water and a corresponding freshening of it. The extent to which the sheet has been undermined by subterranean erosion indicates a considerable antiquity. It is moreover possible that the Otero beds do not really underlie the lava, as they appear to do, in which event our only clue to the age of these beds is inapplicable.

The Otero Formation, as already described, consists of marls with gypsum and saline beds. The upper surface wherever exposed seems a plane and the line between the Otero and Tularosa beds is sharply defined. Wherever the level of the Otero beds is reached, as in the playas and streams about the margin of the basin, saline conditions prevail. Sometimes these salt flats are bare and covered with a thick deposit of salt and alkalis as well as gypsum, while in other cases there may be some soil commingled and the surface is sparsely covered with "salt bush," "salt grass" and other plants of the distinctly saline flora. Along the margins, where the fans from the canons have added to the original deposits, the flora is increased by grease-wood (*Laria*) mesquite and the typical desert facies. The salts upon the playas differ in different cases. In some cases, when dry, there is a layer of nearly pure salt (chloride of sodium) several inches thick. More frequently other salts occur in considerable abundance. When carbonate of soda preponderates it will often form a dense crust in which little common salt is a prominent ingredient. Borax and carbonate of potassium also occur under somewhat different conditions. There seems to be considerable uniformity in the amount of salt in the several divisions. Thus in the series of playas north of the barrier above described as separating the great western salt lakes into two portions an average of two samples gave over 6 per cent of salt, while to the south of the Soda lake which is the southern part of this chain gave an averge of 14.6 per cent. besides large quantities of other salts. This might seem to indicate a tendency to concentrate toward the southern part of the area. Nevertheless the area near "Mal Pais spring" which issues from the southern end of the lava sheet, and the flats of the northern end of the old lake Otero are heavily charged with salt. An average of over 15 per cent was found here without including several lakes whence commercial supplies of salt have been taken and which afford a continuing supply of the pure mineral.

All the arroyos in the east side of the basin are saline. The water flowing in Lost river, for example carries 7 per cent salt while soil in Tularosa arroyo runs 7.8 per cent. The salt lake into which Lost river flows is saturated brine and

furnishes commercial supplies. Analyses of the "white sands" show that this gypsum sand contains very little salt.

From what has been said it will appear that along the entire western border of the old lake the later formation has been removed, perhaps by combined wind and water action, leaving the Otero saliferous formation exposed over several townships, the material therefrom having been driven eastward by the prevailing winds. The eastern margin is suffering destruction in another way. Streams from the Sacramento mountains attack the sandy upper layers (Tularosa formation) and by driving their waters against the advancing dunes, forming deep arroyos and, preliminary to them, series of sink holes in which in some cases water may be heard running. The arroyos are extended and new ones are formed by the confluence of these sink holes. During wet times the roof of such caverns may cave in and we have found the bodies of cattle, head downward, in such falls. It is apparent that solution rather than erosion is the great agent of destruction here. The arroyos so formed may end abruptly against the central dune area or may form salt flats along its eastern margin. These arroyos are covered with salt grass and salt bush and have the usual saline efflorescence.

Much of the drainage from the east is not by way of open arroyos but reaches and even penetrates the Otero formation and passes through underground channels. Frequently these underground waters meet obstacles, or perhaps create them by depositing lime and gypsum, and so are forced to find an escape at the surface. These springs have a considerable artesian head, building up cones to the hight of twenty-five feet or more. Attempts have been made to utilize these artesian waters for irrigation but in all cases so far as followed up the results have been disappointing because of the saline impurities in these waters. Excavation has in some cases opened large subterranean chambers in the vicinity of such springs and the soil is marly and inapt for cultivation.

The Tularosa Formation has been incidentally described. It consists of sandy marl largely gypsiferous and moderately saline. It is usually covered with scanty desert vegetation and is rolling from the dune formation usually accompanying it. The presence over its entire extent of recent fresh-water

shells serves to indicate a comparatively fresh condition of the waters during the hight of the period.

Economic Exploitation. Some efforts have been made to utilize the gypsum sands, a company having been formed operating from Alamogordo for the manufacture of cement and artificial stone. It would appear that the more impure deposits occasionally occur in such mixtures with earth and vegetable matter as to require no retarder and simply need to be partially burnt to be ready for use. Artificial stone and stucco are produced but much remains to be done in the practical exploitation of what will sometime prove a great industry and afford a substitute for the lumber which at no very distant date will disappear from the southwest. Mexico affords an illustration of the great variety of uses to which a cheap cement may be put. Irrigation ditches and wiers as well as very substantial buildings are constructed of combinations of adobe, poor brick, and cement. In this country the use of slow setting ("dead burnt") plasters is not in vogue so that great care is necessary to get the right degree of dehydration.

The entire region is strictly saline and the thin covering of sandy marl of the Tularosa formation does not disguise the fact, though in the vicinity of the talus fans, especially on the east side of the valley, there is a fringe of good soil which will prove very productive when irrigated with fresh water. Such towns as Tularosa and La Luz near the base of the mountains are surrounded by thrifty orchards and alfalfa fields. There is little doubt that mountain reservoirs may do much towards the reclamation of a part of this area, but in the bed of the lake out from the immediate margin the salinity of the Otero formation will always impregnate the superficial layers.

Although the only economic use so far made of the vast deposits of salts has been that of the local stock men who occasionally drive into one of these flats and shovel up a load of salt, is is probable that a large industry will one day be carried on here. It will be found possible to evaporate the brines by a solar process on a very large scale and the cement for making the pans is immediately at hand. Cheap coal

for refining will be available and it is only a matter of time when salt, soda and borax works will be erected.

It is not impossible that fresh water could be found by deep drilling and a partial artesian head would probably be found. In this event the exploitation of the district will be facilitated. If one or more of the extensive irrigation schemes now on foot are carried to a successful completion still greater impetus will be given to manufacturing enterprises in this valley.

In conclusion I have to thank Mr. A. J. Hunt and my son, Mr. H. N. Herrick, for assistance in the work covered by the present paper. The chemical work involved was all done by the latter. I also am indebted for sundry suggestions to Dr. W. G. Tight of the University of New Mexico.

EDITORIAL COMMENT.

THE COLOSSAL BRIDGES OF UTAH.

Mr. W. W. Dyar describes and illustrates in the *Century Magazine* for August, another great American wonder. Time was when the natural bridge of Virginia was held to be worthy of a long journey. It is rare indeed that the erosive forces are so balanced against the varying endurance of natural rock cliffs as to excavate and undermine and leave intact a span of the firmer rock arching over an eroded softer stratum. Rare as this may be it is certainly rarer that arches as majestic as those described by Mr. Dyar should be wrought and preserved through the vicissitudes of Pleistocene time and remain to the present—indeed it is certain that no natural bridges equal to these are known in any part of the world. The unexplored interior of Africa may disclose natural arches of equal hight and span, but until such are discovered those of Utah will very easily rank first and will challenge the admiration of American travellers.

These bridges are near the head of White canyon in San Juan county. "Their walls and buttresses are composed of pinkish sandstone, streaked here and there with green and orange-colored moss or lichens." The Caroline bridge, by a series of rough triangulations was found to measure two hundred

and eight feet, six inches from buttress to buttress across the bottom of the canyon. From the surface of the water to the center of the arch above the hight is one hundred and ninety-seven feet, and over the arch at its highest point the solid mass of sandstone rises one hundred and twenty-five feet farther, to the level floor of the bridge. The causeway of the bridge, over which an army could march in columns of companies, as remarked by Mr. Dyar, is therefore three hundred and twenty-two feet above the stream. The floor of the bridge is one hundred and twenty-seven feet wide. Unfortunately, owing to the winding course of the canyon at this point and the consequent lack of perspective, the travelers were unable to obtain photographic views conveying to the eye any adequate expression of the majesty of this bridge. Still Mr. Dyar succeeded in getting a sidewise view and the *Century Magazine* has reproduced it from a half-tone plate engraved by S. Davis.

Three and a half miles above the Caroline bridge is the Augusta bridge, which is the most remarkable and majestic seen by the explorers. Of this a colored half-tone by Henry Fenn is given by the *Century Magazine*, occupying a full page, made from a photograph. This is described as magnificent, symmetrical and beautiful in its proportions, "so as to suggest that nature after completing the mighty structure of the Caroline had trained herself for a finer and nobler form of architecture." Here the cross-section of the canyon is three hundred and thirty-five feet and seven inches from wall to wall. The splendid arch is of sandstone sixty feet thick in the central part and forty feet wide. The opening beneath the arch is three hundred and fifty-seven feet in perpendicular hight. The lateral walls of the arch rise perpendicularly nearly to the top of the bridge where they flare suddenly outwards, giving the effect of an immense coping or cornice overhanging the main structure fifteen or twenty feet on each side, and extending with the greatest regularity and symmetry the whole length of the bridge. A large rounded butte at the edge of the canyon walls seems partly to obstruct the approach of the bridge at one end.

"Here again," in the words of Mr. Dyar ,"the curving walls of the canyon and the impossibility of bringing the whole of the great structure into the narrow field of the camera, except

from distant points of view, render the photographs unsatisfactory. But the highness and grace of the arch are brought out by the partial view which Long obtained by climbing far up the canyon wall and at some risk crawling out on an overhanging shelf. The majestic proportions of this bridge, however, may be partly realized by a few comparisons. Thus its hight is more than twice and its span more than three times as great as those of the famous natural bridge of Virginia. Its buttresses are one hundred and eighteen feet farther apart than those of the celebrated masonry arch in the District of Columbia known as Cabin John bridge, a few miles from Washington city, which has the greatest span of any masonry bridge on this continent. This bridge would over-span the capitol at Washington, and clear the top of the dome by fifty-one feet, and if the loftiest tree in the Calaveras grove of giant sequoias in California stood in the bottom of the canyon its topmost bough would lack thirty-one feet of reaching the under side of the arch."

THE LITTLE BRIDGE.

(From a half-tone plate engraved by J. W. Evans.)

The Little bridge, of which a cut is herewith shown, taken by permission from the *Century Magazine*, is a mile and half below the Caroline bridge. Its dimensions are not so large as those of the Caroline and Augusta bridges. It has a span of two hundred and eleven feet, four inches. The under side of the arch is one hundred and forty-two feet above the bottom of the canyon. The crown of the arch is eighteen feet, eight inches thick and the roadway is thirty three feet, five inches in width. "The slenderness of this aerial pathway and the fact that the canyon here opens out into a sloping valley beyond rendered it possible for the camera to give a proper impression of loftiness. Indeed, judging from the photographs alone one might suppose this to be the highest of the three bridges, whereas in fact it has but little more than one-third the altitude of the wonderful Augusta arch. It was comparatively easy to reach the top of this bridge, and among Long's notes I find the following: 'Rode our horses over. I am the first white man who has ever ridden over this bridge.'"

The foregoing descriptive notes are condensed from the interesting account by Mr. Dyar, who used the notes made by Mr. Horace J. Long who in company with a cattle man named Scorup visited the region March 13, 1903. Mr. Scorup had seen the bridges in the fall of 1895, but they were discovered earlier in the same year by Emery Knowles.

The region is one of the Cliff Dwellers, and abounds in their remains. It is evidently destined to become one of great interest. The *Century Magazine* is to be thanked for the beautiful but simple presentation of these natural wonders to the attention of the public.

N. H. W.

REVIEW OF RECENT GEOLOGICAL LITERATURE.

Faune cambrienne du Haut-Alemtejo, par J. F. NERY DELGADO ["Communicações" du Service Geologique du Portugal Fom. V., Lisbonne, 1904].

This communication is of much interest to palæontologists in making them acquainted with a new fauna of Cambrian time in southern Europe.

It is contained in what has been denominated the "Upper Cambrian" of Portugal as distinct from the "Lower Cambrian," which M. Delgado places on a par with the Algonkian, Huronian, Keweenawan, etc.

The fauna is contained in a schistose group of beds immediately subordinate to a heavy body of limestones which he designates as the limestones of Villa Boim. The underlying beds are chiefly quartzytes 100 metres thick. The fossils were taken from a thin layer of slate about a centimetre thick in the top of the quartzytes. Beneath the quartzytes above mentioned are other quartzytes, slates, etc., of great thickness, of the same series.

The fossils were very irregularly distributed in the slates and were preserved in spathic iron which by its oxidation discolored the rock and revealed the position of the fossils. These are consequently moulds of the tests showing the outer and inner surfaces of the fossils. The greater part of them are the remains of the heads of trilobites; the movable cheeks are usually wanting, and fragments of the thorax and pygidia are rare. The fauna is chiefly composed of species not hitherto known or described. Besides the trilobites there are several species of pteropods (Hyolithidæ) lamellebranchs and brachiopods.

The existence of several species of lamellibranchs in this fauna is worthy of attention; they are of small size and carry genera described by Dr. Henry Hicks from the Tremadoc down to this horizon.

There are innumerable detached heads and pygidia of trilobites of the genus Microdiscus imbedded with the other fossils. No example of an inrolled trilobite of any genus was found.

Upon the varied forms referable to the genus Microdiscus M. Delgado bases the opinion that this fauna is allied to that of Olenellus in America.

However, if a comparison is made with the fauna of Wales studied by Hicks this Portuguese Cambrian fauna is best represented by the Solva group fauna of Wales.

In the Siberian Cambrian fauna described by von Toll there are a number of related forms especially in the genus Microdiscus. M. Delgado considers that the Portuguese species showing relation with the Olenellus fauna are of greater importance than those which connect it with the Paradoxides fauna.

Of Paradoxides five species were found, indicated either by a sufficiency of parts to determine the species, or by fragments.

In this memoir M. Delgado elaborates the character of a new genus —*Hicksia,* founded on a group of species resembling Salter's species *Conocoryphe humerosa*: it has the tumid cheeks and glabella of Solenopleura with the smooth test of Liostracus, but the back of the glabella is narrower than in Liostracus; like the latter it has a quite small pygidium. No less than nine species referable to this genus are described.

Of the genus Microdiscus five species are described. They are mostly smooth forms such as are found in the Olendellus fauna and faunas referred to that horizon.

Three Hyolithes are described of which two are referred to species described of the Lower Cambrian of America.

Though they are minute, considerable variety is found in the species referred to the Lamellibranchiata, as may be seen by the generic names Posidonomya (?) Modiolopsis, Synek, Davidia (3 species) and Ctenodonta.

The Brachiopoda are rather meagerly represented by Obolla (2 species) Acrothele Lingulepis (2 species) and Lingulella (3 species)

Six plates containing numerous photographic figures of the fossils serve to give completeness to the memoir. These have the merit of accuracy and eliminate the personal equation, but for such small figures as those of the brachiopods and lamellibranchs they do not present determinate characters. Such a picture illuminates the fossil only from one side and fails to bring out all the details. An enlarged drawing by the author representing what he saw in the fossil, viewed from different points, would help to fix the descriptions in the reader's mind.

M. Delgado is to be congratulated on the complete manner in which he has worked up this fauna contained in a little bed of the Cambrian rocks of Portugal, and thus given a fixed horizon from which to determine the age of the connected formations above and below it. G. F. M.

North America. By ISRAEL COOK RUSSELL. Pages x, 435; with 8 colored maps and 39 other illustrations. New York, D. Appleton & Company, 1904.

This excellent compendium of geographic, climatic, biologic, geologic, and ethnologic description of our North American continent is one in a series of convenient octavo volumes treating of "The Regions of the World." For this task the author has given in previous works full guarantees of his ability, having published, besides many and voluminous reports of the United States Geological Survey, several geographic works during the years 1895 to 1898, on the lakes, glaciers, volcanoes, and rivers of North America.

Professor Russell says in the preface: "While writing this book I have become more and more impressed with the incompleteness and inadequacy of the printed records relating to the geography of the continent of which it treats. Extensive tracts, particularly in the far North, have not been traversed by observant men, vast areas throughout the continent have not been surveyed and mapped, and even in the somewhat thickly inhabited portions of the more enlightened countries there are large districts in reference to the geography of which there is but little critical information available. Under these conditions it seemed best to select typical examples of various geographical features from the better known portions of the continent to represent the conditions throughout the less thoroughly explored domain in which they are situated, and at the same time serve to illustrate the highly creditable advances made by American geographers in definitely formulating the principles of physiography. The book may, in a measure, be considered as an attempt to present in popular form a report of progress concern-

ing the study of the geographical [illegible] of North America at the beginning of the twentieth century [illegible]

The chapter on geology [illegible] pages [illegible] ingly of the growth of the continent [illegible] and more at length its resources [illegible] map of three [illegible] rocks. Another colored map [illegible] but by transposition reverses the [illegible] and [illegible] sheets.

Index [illegible] and Henry McC[illegible] [illegible] of Alabama. [illegible] views from photographs [illegible]

This report [illegible] sources of the state [illegible] vious publications of the state [illegible]

Alabama ranks as the [illegible] which during the year [illegible] the mines of nearly $[illegible] state, by 42 coke furnaces [illegible]

The state is [illegible] area of 8,800 square miles [illegible] field. Twenty-[illegible] from 18 inches to [illegible] feet. [illegible] thirty years of coal mining in [illegible] duction was no more than [illegible] thirty years to 11,700,753 [illegible] $17,000,000, giving to the state the fifth [illegible] of the Union.

The Glaciers [illegible] Professor Geology [illegible] of Commercial Geography, University of California. [illegible] *ings of the* [illegible] III, Series II, June, 1904.)

The author of this paper [illegible] and charts made by the earlier [illegible] of the Pacific coast and islands of northwest America, and has embodied the results of this study in the above named paper [illegible] charts. All accessible maps of these regions [illegible] 1852 had been compiled by Tebenkof, to whose great atlas of thirty-eight charts Davidson has access as well as to the English, Spanish and Russian originals from which Tebenkof quoted [illegible] Davidson's work commences with glaciers mapped on a volcano [illegible] Lat. 52°, Long. 174° W, and embraces the vast [illegible] Stikine river, Lat 56¾, Long. 131¾ N., a coast [illegible] tractiveness and accessibility [illegible] student of glacial geology the largest and best fields [illegible] polar regions.

After citing the possible existence of glaciers on Atkha island, Davidson reviews at considerable length those on Unalaska island, the Peninsula of Alaska, Cook's inlet, Kachemak bay, Kiani peninsula, Prince William sound, Yakutat bay and from Glacier bay to Stakheen river.

Tebenkof's charts mark the positions of thirty glaciers; these, as noted by Davidson, are (a) on the southeast coast of the peninsula of Alaska north of Agripina bay, *three;* (b) on the southeast coast of Kenai peninsula, *eleven,* then follow (c) the great glaciers fronting on the ocean between Icy bay and Lituya bay, including Malaspina, Yakutat and Fairweather glaciers; the apparently recent obliteration of Icy bay and the uncovering of the northeastern part of Yakutat bay and of the entire Disenchantment bay region are marked features in this group; (d) the next group is on the north shore of Cross sound, where Tebenkof charts *eight* important glaciers, *two* of which indicate that Taylor bay has been blocked by an advance of Brady glacier, and that the *three* easterly glaciers as mapped by Tebenkof, indicate an extensive retreat which has uncovered Glacier bay and its entire group of tributary glaciers. Davidson recites quite reliable Indian legends supporting the evidence furnished by these early charts: (e) the most southerly glaciers mapped by Tebenkof are, *one* on the north shore of Taku inlet and *one* on the east shore of Frederick sound north-northeast from Wrangell narrows; this glacier must have come from the great Stakheen mer de Glace, and in 1835 filled Frederick sound and Wrangell narrows with bergs. Glaciers also reached tide water here in 1867—but today these glaciers do not flow into tide water with sufficient energy to give off bergs.

These constitute the glaciers mapped up to the date of Tebenkof's atlas and when compared by Davidson with later chartings show marked retreat in most cases.

Later records are also fully reviewed by Davidson. The most interesting points brought out by him are: (1) the probable recent opening of Doran strait and Harriman fiord by the recession of Washington and Barry glaciers, thus permitting the Harriman expedition in 1899 to first expose the splendid group of glaciers to the west of Doran strait. (2) The retreat of two and one-half miles of the Kachemak bay glaciers. (3) The changes since Vancouver's survey in the Port Valdes region. (4) The probable recession in the glaciers of Taku inlet since Lt. Whidbey's description in 1794.

Davidson concludes, p. 92: "So far as we can judge there has been a general recession of the glaciers through Aleutian islands, the peninsula of Alaska, and from Cook's inlet to Portland canal; except where they come directly or almost upon the broad ocean."

The evidence of advance seems clear at Wimbleton or Taylor bay, just inside cape Spencer, at Icy strait, since the survey of Whidbey; but the recent topographical survey by the United States Coast and Geodetic Survey shows a retreat behind the terminal moraine which it has left as a record.


148°
146°
128°
126°
60°
126°
58°
128°
56°
58
56
CHUGACH
MOUN
Valdes
PRINCE WILLIAM
SOUND
Latouche Id
G. Cleare
GULF

The Malaspina glacier has filled and obliterated the Icy bay of Vancouver and Tebenkof; the recent Canadian survey indicates that the glaciers of Lituya bay have shortened the deep arms described by La Perouse: and the La Perouse glacier upon the ocean shore shows positive signs of advance according to the reports of the Harriman expedition of 1899.

"Nevertheless in this region of advance the immense ice blockade at the head of Yakutat bay, so well depicted by Malaspina and confirmed by Tebenkof, has been carried away, and the Turner and Hubbard glaciers now discharge into the sharp bend at the head of the bay. Puet reported there was a small inlet that extended N. 55° E., one league behind the ice front, July 27th, 1794."

This excellent work should form the basis of a thorough survey of all the more important glaciers therein mentioned; and should be in the hands of those who visit these regions as a general guide and to induce close study and comparison. M. M.

Dodge's Elementary Geography. R. E. DODGE. 231 pp. Rand, McNally & Co., Chicago, New York, London., Oct. 1903. Price 75 cents.

In the multiplicity of geographies that are appearing in the United States constructed on the more modern ideas, it is sometimes a little difficult to discover their individual distinctions. There are physical geographies, and geographical geologies, as well as geographical histories. In nearly all of the recently published modern geographies the lines devoted to political geography are rather few, and those devoted to physiography are many and long. Dodge's geography is more evenly balanced. While its chapters and paragraphs bear the term of political geography, the maps that illustrate them are both political and physical. Of the latter North America, for instance, is shown by a beautiful relief map and also by a physical map, followed by a political map. The United States is also thus thrice mapped. The different sections of the United States are politically mapped and the facts of their industrial differences are clearly set forth in the text. This book dwells more on the facts of geographic distribution of the inhabitants and their occupations than upon the physical causes of such distribution. It is proposed by the author to treat fully of the physiographic elements of geography in a more advanced work. The volume is bountifully illustrated by beautiful half-tone engravings from photographs. On the 217 pages are numbered 375 such pictures. It would be difficult to speak too highly of the excellence of this work as an elementary school geography. N. H. W.

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A rejoinder to Dr. Dall's criticism on Dr. Spencer's hypothesis concerning the late union of Florida with Cuba. (Am. Geol., vol. 34, p. 110, Aug., 1904.)

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Age of the Missouri river. (Am. Geol., vol. 34, p. 80, Aug., 1904.)

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Orbicular gabbro-diorite from Davis county, North Carolina. (Jour. Geol., vol. 13, pp. 294-304, May-June, 1904.)

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The Baraboo iron-mining district. Bull. 13, Wis. Geol. Nat. Hist. Sur., 23 plates, pp. 199, map, Madison, 1904.

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Deposition of the Appalachian Pottsville. (Bull. G. S. A., vol. 15, pp. 267-282, plate, June, 1904.)

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The Laramie and Fort Union beds in North Dakota. (Jour. Geol., vol. 13, pp. 290-294, May-June, 1904.)

CORRESPONDENCE.

THE TYPE OF AVICULIPECTEN. I was interested to see Mr. G. H. Girty's note on "The typical Species and General characters of *Aviculipecten*, McCoy. I have recently had occasion to examine this question when working on the Pectiniform shells of the British Carboniferous rocks and published certain results in Pt. II, Vol. II, of my

Monograph of British Carboniferous Lamellibranchs, published in the Palæontographical Society's volume for 1903. I wish Mr. Girty had had access to this Monograph before he penned his note because unfortunately most of the scientific names quoted by him turn out to be mere synonyms of previously described species, or belong to genera distinct from *Aviculopecten*.

I think, in the unfortunate circumstance of the absence of any definite indication, that it is a good and simple rule to regard the first described species as the type of the genus. All that Mr. Girty has to say as to the locality is important, but nevertheless an author must have some object in view in the arrangement of his species, and as McCoy adopted no alphabetical order, we must presume that he intended *A. planoradiatus* to be the type. Unfortunately, however, he had erected this species on a left valve in ignorance of the fact that he had previously described the right valve as *Pecten* [illegible]; consequently this name has the priority. Again McCoy did not recognize that his *A.* [illegible] had been described long before by Portlock under the name *Pecten semicostatus*, which name is prior even to *P.* [illegible] McCoy. The hinge plate of this species is almost smooth, (vide fig. 11, Pl. XIII, op. supra cit.), the fine parallel striae are only to be seen by a microscope. I have found it necessary to remove A. papyraceus Sow. sp., A. granosus Sow. sp., and A. concavus McCoy sp. from *Aviculopecten*, because they have a narrow linear hinge plate, and the posterior is not marked off from the rest of the valve. I have referred them to *Pterinopecten*, Hall. Neither of these three species can in any way be regarded as the type of *Aviculopecten*. I have pointed out Zittel's mistake in referring *A. papyraceus* Sow. sp. as the type of that genus, Op. supra cit. p. 51. It will be noted in my monograph that I have restricted Aviculipecten to forms with a long hinge line, well marked elongated ears, but even so I feel that future observations will probably necessitate a still further restriction of this genus.

WHEELTON HIND

Stoke on Trent, England, July 21, 1904

PERSONAL AND SCIENTIFIC NEWS.

AT A RECENT MEETING OF THE VIRGINIA BOARD OF AGRICULTURE an appropriation was voted for a Geological Survey of the mineral resources of Virginia. The survey will be conducted jointly by the State Department of Agriculture and the Virginia Polytechnic Institute. Dr. Thomas L. Watson, professor of geology in the Polytechnic Institute, was appointed Geologist-in-charge of the survey.

MAJOR A. W. VOGDES, San Diego, Cal., has recently been retired from active service in the United States army, and has

returned to his home in San Diego. He is building up a large geological library for the west coast.

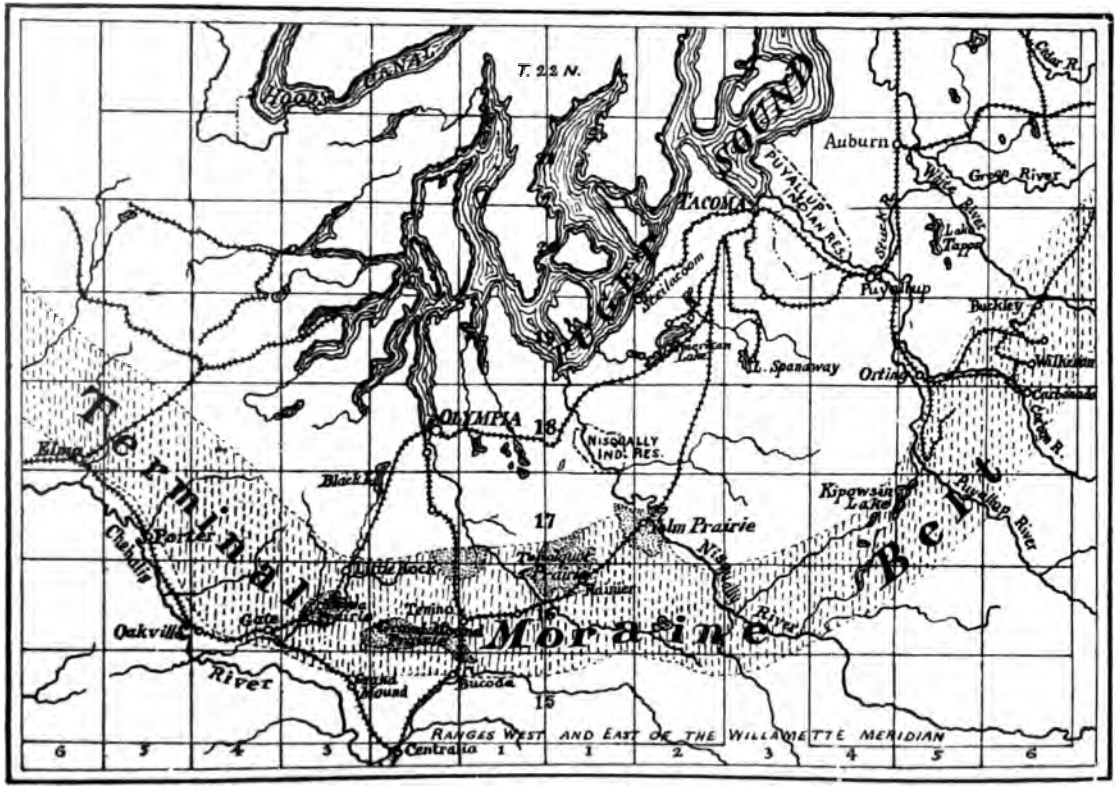
DR. I. C. WHITE, state geologist of West Virginia, has leave of absence for six months and has sailed to Brazil where he will examine and report on the coal fields of Rio Grande do Sul, the most southern state of Brazil. He left the United States July 5, and will return some time in December.

PROF. G. P. GRIMSLEY, of Topeka, Kansas, has been appointed assistant geologist of West Virginia, and began work Aug. 1, in the preparation of vol. iii, on clays, building stones, limestones, etc.

THE OHIO GEOLOGICAL SURVEY is carrying on both office and field work during the present summer. The following indicates the principal lines of work which the survey is at present conducting. Professor Edward Orton, Jr., State Geologist, is completing his part of the work on cement and its uses and is also editing the manuscript for two other bulletins. It is his expectation that four bulletins will be published during the remainder of the year. Professor John A. Bownocker with an assistant is engaged in studying and mapping the distribution of the Pittsburg and Meigs Creek coals in the eastern part of the state. Professor Charles S. Prosser with an assistant is studying the stratigraphy of the Upper Silurian, Devonian and Carboniferous formations. Part of this work is directed toward the correlation of the Ohio formations with those of Pennsylvania and New York and a report is in preparation describing their stratigraphy in detail.

THE CLASS IN FIELD GEOLOGY of the Ohio State University during the spring term of this year, under the guidance of professor Prosser, studied the various formations which are found in central Ohio. The Devonian limestones (the Columbus and Delaware formations), the Olentangy and Ohio shales of the Devonian; the Bedford shale, Berea grit, Sunbury shale, Cuyahoga and Black Hand formations, Logan shales and Pottsville formation of the Carboniferous comprise the formations which were studied the most thoroughly. The Saturday field trips consumed the entire day. The rocks and fossils collected were later studied in the laboratory and a thesis prepared by each student which contained a description of the sections studied, together with a summary of the geological literature for central Ohio relating to the above mentioned formations.

THE DEVONIAN VOLUME of the systematic reports of the Maryland Geological Survey is nearing completion. It will be a composite work consisting of three parts: the Paleodevonian by professor Schuchert, the Mesodevonian by professor Prosser and the Neodevonian by Dr. John M. Charlse.



DRIFT AREA OF THE SOUTH PART OF PUGET SOUND.

THE

AMERICAN GEOLOGIST.

VOL. XXXIV. OCTOBER, 1904. No. 4.

GLACIAL AND MODIFIED DRIFT IN AND NEAR SEATTLE, TACOMA, AND OLYMPIA.

By WARREN UPHAM, St. Paul, Minn.

PLATE XIII.

These three cities in the state of Washington, the first and second situated on the eastern shore of the southern part of Puget sound, and the third at the end of the most southern arm of the sound, are respectivly its foremost and second commercial ports, and the state capital. Last year I spent several days in their vicinity, examining the drift deposits of the region, coming to it by the Northern Pacific railway, and extending my journey across this drift area and a wide driftless tract on its southwest side, to the ocean shore west of Gray's harbor.

Although my observations are necessarily very incomplete, as noted in this paper, it is hoped that they may serve some useful purpose as a slight contribution to the description and history of the very interesting glacial and modified drift formations of the Puget sound lobe of the ice-sheet.*

The most notable feature of these formations seems to me to be the very large proportion of the modified drift, or stratified gravel, sand, and fine silt, deposited by streams discharged from the ice-sheet, apparently during the time of its final melting and departure at the end of the Glacial period. In the greater part of New England and in Minnesota and North

* Previous descriptions of these drift deposits, with discussions of their origin and stages of the Glacial period, have been given by BAILEY WILLIS, in a paper entitled "Drift Phenomena of Puget Sound," *Bulletin, G. S. A.*, vol. ix, 1898, pp. 111-162, with five plates, containing many details of his observations, and quoting from a manuscript report of a reconnoissance by Prof. I. C. RUSSELL. A large part of the same studies is also presented by BAILEY WILLIS and GEORGE OTIS SMITH in the Tacoma Folio, No. 54, 1899, of the *Geologic Atlas of the United States.*

Dakota, where I have made extensive studies of the drift, the proportion of the glacial drift or till to the modified drift averages, as I estimate, generally about as two or three to one. Here, however, as on cape Cod, Nantucket, Martha's Vineyard, and Long island, the ratio is reversed, so that the modified drift is twice or thrice as abundant as the till.

Referring the modified drift mostly or almost wholly to derivation, from formerly englacial and finally superglacial drift, which had been gathered up by the slowly flowing ice-sheet into its lower quarter or third part, but which was at last uncovered and exposed on the surface of the ice when nearly all its thickness had been removed in the final melting, and thence being washed down by superglacial drainage to the ice border, I therefore regard the large volume of these stratified drift deposits as good evidence of a very long duration of the glaciation. The lower part of this glacial lobe was abundantly charged with englacial drift, brought partly from the Cascade range on the east and partly from the Olympic mountains and the mountains of Vancouver island on the west, but doubtless also in an equal or greater degree supplied from the intervening area of lowland, fifty miles or more in width, and from the bed of the sound, with its many canals, bays, and inlets.

Pleistocene history probably began with an epeirogenic uplift, elevating this side of the continent at least 3,000 to 5,000 feet higher than now, as is known on the coast of California by the deep submarine valleys described by Davidson,* which great elevation caused glaciers to be formed first on the mountains and to extend thence outwards as piedmont glaciers on the lowlands. At length the glaciers of such local origin became confluent upon all the country. A general ice-sheet then enveloped British Columbia, and indeed extended, as I believe, during a very long period, from the Pacific to the Atlantic, across the entire width of Canada and the northern United States. At last, beneath the long continued ice burden, all this northern half of North America sank to its present altitude, or mostly a few hundred feet lower, bringing again a temperate climate, with plentiful melting of the ice every summer along all the border of the continental icefields, which then were somewhat rapidly melted away.

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* *California Academy of Sciences, Bulletin*, vol. ii, pp. 265-268, Jan., 1887; do., *Proc. Geol., third series*, vol. i, pp. 73-103, with nine plates, 1897.

The channeling of the deep valleys now occupied by Puget sound and its many inlets, ranging from common depths to 100, 300, and 500 feet to a maximum of 918 feet a few miles north of Seattle, must be ascribed, as I think, to river erosion during the time of continental elevation inaugurating the Ice age.

While these valleys were being filled gradually by the growing piedmont glaciers, sometimes retreating and again readvancing, as we must suppose, their early till might become buried beneath stratified drift and a forest, which in their turn would be later overridden by the glaciers and long covered by the general glaciation. Therefore the intermittent glacial action shown by deposits of till underlying and overlying stratified drift, which sometimes contains layers of lignite, noted in various localities of the Puget sound region and attributed by Willis and Russell to successive and distinct stages of glaciation, may perhaps be more probably explainable by moderate oscillations of the margins of the early glaciers, requiring no long stage, nor very notable secular climatic changes, as the lower till would represent a time before the broad and general ice accumulation.

After the glaciers flowing outward from the mountains at the east and west had become united, the Puget sound basin was evidently filled by a typical lobe of the continental ice-sheet, the snow and ice being amassed to the greatest thickness and hight upon its central and axial part, thence flowing outward to the west through the strait of Juan de Fuca, and to the south, where it terminated at a curved border nearly on the same latitude with Mt. Rainier. From the sites of Seattle, Tacoma, and Olympia, the currents of the ice-lobe moved southeast and south, carrying drift from the area of the sound upward fully thirty miles to a hight of 1,000 to 1,600 feet above the sea level near the base of the great snow-covered cone of Rainier, and reaching several miles farther south, to the latitude of that majestic white mountain at the most southern limits of the icefields, about 100 to 400 feet above the sea, southwest, south, and southeast of Olympia.

The lowest place in the southern watershed of Puget sound is about three miles southwest from Olympia, between that arm or inlet of the sound and Black lake, some two miles long, at the head of the Black river, a tributary of the Chehalis river.

which flows west to the sea at Gray's harbor. The altitude of Black lake is about 160 feet above the sea level; and the watershed, in a wooded swamp about a quarter of a mile wide, close north of the lake, is only 5 to 10 feet higher. The railway from Olympia to Gray's harbor passes near this lowest sag of the water divide.

Over this low pass a river doubtless outflowed for a considerable time when the icefields covering the southern half of the sound were being finally melted. Below the hight of about 170 feet, therefore, evidences of standing water ponded against the retreating ice margin are to be expected in the valleys and along the shores of the sound from Olympia to Seattle, or farther north, their northern limit being reached wherever the melting of tne outer western part of this ice lobe in the great valley of the strait of Juan de Fuca coalesced with the melting of its southern part so as to remove the ice barrier and admit the sea there along the west side of the sound.

But much of the modified drift of this region, its far greater part, is above the limit of lacustrine effects from the glacial lake so overflowing to Black lake and river. On the hills and plateaus bordering the sound, mostly 200 to 300 feet or more above its sea level and rising thence gradually on each side toward the Cascade range and the Olympic mountains, great areas of stratified drift sand and gravel are found, which must be attributed to stream deposition attendant upon the recession of the ice-sheet, with free descent of these streams, which would deposit the greater part of their coarse modified drift close to their places of discharge from the waning icefields. Thus the highlands along this south half of Puget sound were overspread by stratified drift progressively from south to north, as the ice border was gradually melted back.

Queen Anne hill, in the northwest part of the city of Seattle, rising with moderately steep slopes to a massive, gently rounded top, or rather to two such hilltops, each about 460 feet above the sea level of the sound, a half mile distant, consists of stratified sand and gravel, cut in many places 6 to 10 feet deep for new streets, and on its steep southern side cut 25 to 50 feet in the same modified drift. Much of it is quite irregularly bedded, and in the deep southern cuts the beds are largely inclined 10° to 20° northward, dipping toward the center of the hill. It

is mostly sand in the lower parts of its deepest sections, but includes gravel beds nearly everywhere for the highest 5 to 10 feet next to the surface, with rounded cobbles up to 6 to 8 inches in diameter. Boulders are very rare or wholly absent.

Only in one place on this hill was any till observed, that being in a street cut on the northwest slope of the eastern summit, about forty rods from the city water works tower, which stands on the top of this east part. There, 25 to 30 feet below the top of the hill, a lenticular mass of true till, 30 feet long, with a maximum thickness of 5 feet, was seen inclosed in an exceptionally coarse gravel deposit, the till mass being 5 to 10 feet below the original surface. All around it was very coarse gravel, in part showing a gradual transition, but mostly with a definite and abrupt line of separation. The explanation that seems most satisfactory would refer the modified drift of this large and high double-topped hill to deposition under the edge of the departing ice, when it had become thin and drift-covered on account of its surface melting. Streams gathering the superglacial drift from parts of the icefields a little farther north probably poured down through crevasses near the ice front, amassing the great hill in a two-parted cavity melted beneath the ice. The deposition of the modified drift progressed as the subglacial cavity was melted and enlarged; and the mass of till mentioned appears to have been derived from superglacial drift that was allowed to fall by the full melting of the ice beneath it, without becoming modified by water assorting and stratification.

Duwamish head, and the plateau extending from it southward, a mile wide between Elliott bay and the main sound, rising 250 to 300 feet above the sea level, reached by a ferry trip of two miles west from the docks of Seattle, are, in the lower 100 to 150 feet, horizontally bedded clay, or very fine silt, light gray and nearly uniform in color, mostly exhibiting very fine lamination, evidently laid down in still water. The next higher 100 feet, or more, are sand, yellowish gray, horizontally stratified in the lower part, but very irregularly bedded, with evidence of strong flow and counter currents of the depositing waters, in the upper part, where the sand becomes coarser, with some layers of fine gravel. Above these very thick stratified beds is a sandy till, with little or no strati-

fication, 10 to 20 or 30 feet thick, forming the surface of the plateau, inclosing rather scanty small rock fragments, with a few large boulders. Good sections of the successive deposits are seen in the sea cliffs at and south of the ferry landing, and likewise on the west side of the plateau; and they all seem to me referable to the time of the final melting of the ice lobe, being modified drift with a surface of till.

Most of the area of Seattle city has till on the surface, which rises in very massive, smoothly rounded hills, 250 to 400 feet high. Here, and in the northern suburbs, about lake Union and Green lake, the till has nearly the same very compact and clayey texture, and the same considerable proportion of small stones and large boulders, as the average till of southern and western Minnesota; but it has much fewer boulders than are common in the till of northeastern Minnesota and generally thence east to New England.

Sections cutting through the till on Washington street, two blocks southwest of the court house, at the hight of about 150 to 175 feet above the sound, show it to have there a thickness of only 2 to 8 feet along a distance of about 250 feet, being underlain by light gray, finely laminated shales, which seem to me probably of Lower Tertiary age, like the lignite-bearing shales in the vicinity of Renton, near the south end of lake Washington, about ten miles south-southeast of Seattle. Numerous other sections in this city show the glacial and modified drift to be frequently no more than 10 to 25 or 40 feet thick, with such shales lying beneath and reaching to an undetermined depth.

The massive hills were subaërially sculptured in the shales before the Ice age, and are only thinly veneered with the drift; but in the valleys the drift doubtless attains, in some places, a much greater thickness. For example, we cannot doubt that the long north to south valley occupied by lake Washington, whose water surface is 22 feet above the sound and the sea, with a maximum depth of 222 feet, had, along some route now filled by the drift, a continuous preglacial connection, nowhere less than 200 feet deep below the present sea level, joining the lake valley with that of the sound.

Within the third of a mile eastward from Renton to a brickyard, which uses the Tertiary shales, the bluff rising at the

south side of Cedar river has these shales at its base, eroded to an undulating contour, on which till was deposited to the thickness of 5 to 15 feet, succeeded by 75 feet of sand and gravel, containing cobbles up to 6 or 8 inches in diameter.

Stewart street in Seattle, at its summit level, about 175 feet above the sound, in front of the Hotel Washington, has cut through the thin drift, which there is coarse gravel, into the shales, which contain in that place a layer of lignite, 4 to 6 feet thick, in part clayey, about 10 to 15 feet beneath the original surface, horizontal but here and there considerably contorted as if by the pressure of the overriding ice lobe. The lignite is seen along an extent of fully 250 feet at the upper north side of the street excavation, and also for a less extent on its south side, where this layer outcropped on the natural surface.

In Tacoma, twenty-five miles south of Seattle, till generally forms the surface, which ascends in moderately steep slopes to a hight of 350 feet; but street grading or other and deeper excavations often pass through the till, penetrating into an extensive mass of modified drift, irregularly bedded gravel and sand, probably a subglacial deposit. A notable characteristic of the till here is that many of its small rock fragments, about three fourths of all in some excavations, are well rounded pebbles and cobbles, up to 8 inches in diameter, derived from preglacial valley gravels. Otherwise the till is quite typical, very hard and compact, with only a moderate supply of stones and few boulders, yet having some boulders 2 to 3 feet in diameter or larger.

Till and thick underlying modified drift continue five miles northwest from Tacoma to Point Defiance, where they are well exposed in freshly undermined sea cliffs. Throughout the neighborhood of Seattle and most of the city area of Tacoma, the drift surface is smooth, without the knolls and small ridges peculiar to marginal moraine tracts; but in Point Defiance park, and thence southward eight miles to Chambers creek, it consists of knolly and ridgy till, with more than the ordinary proportion of boulders, possessing thus well marked morainic characters. The knolls, however, as seen on the railways going to the park and to Steilacoom, are seldom more than 10 to

20 feet high; nor does the drift accumulation seem much greater than on the smooth areas.

Southward from Chambers creek, as about Steilacoom and American lakes, and at Parkland and southward on the railway from Tacoma to Spanaway lake, the surface is stratified gravel and sand, in far reaching plains, extending to the drift boundary. These Steilacoom plains, as they are named by Willis, are 250 to 350 feet above the sea. Spanaway lake, one mile long, at the hight of 329 feet, is of the same type as many others inclosed thus by modified drift, being probably the site of a finally isolated remnant of the melting ice border, which was surrounded by the rapidly deposited gravel and sand. When the ice mass melted, it left a hollow and lake.

From Steilacoom, Parkland, and Spanaway lake, only stratified drift gravel and sand were seen along the distance of about twenty-five miles southwest to Olympia and twenty miles onward to Gate, at the edge of the drift. In all that distance, nearly fifty miles, only two or three boulders were seen, these being 3 or 4 feet in diameter, in the fine sand of the modified drift about two miles southwest of Olympia, on the ascent to the watershed near Black lake. The deposition of the sand and gravel took place evidently close outside the retreating ice margin at the end of the Glacial period.

About a quarter of a mile southwest of Olympia depot, on the south side of the railway and near the end of this arm of the sound, is a well exposed section 60 to 100 feet high, consisting of very fine sand and clay beds, all laminated, with no gravel, dipping 2° to 5° eastward. These beds, rarely exposed, form the lower half of the plateau country adjoining the end of the sound; but the upper half, rising to 200 or 250 feet, is sand and gravel, irregularly bedded, often very coarse, with cobbles up to 5 or 6 inches in diameter.

One of the many excavations in this modified drift of Olympia has a part that resembles till. It is a half mile east from the center of the town, and at the estimated hight of 150 to 160 feet, being a dark gray, very compact and very coarse gravel, with abundant stones up to 8 inches, all somewhat waterworn,—thus containing too many cobbles to be regarded as till, and having no boulders. That deposit, 10 to 15 feet

thick, is overlain by 5 or 8 feet of the ordinary coarse yellow gravel.

Although there is little or no till at and near the drift border south of Puget sound, and although that belt has no large drift accumulations, the thin edge of the modified drift presents distinct but very low mounds and knolls, ridges and hollows, more or less referable to the class of marginal kames, which in many drift regions are a conspicuous feature of terminal and recessional moraines. Frequently only 2 to 5 feet high, but occurring in great profusion, by hundreds and even thousands, without any evident system or order of grouping, these peculiar gravel mounds, characterizing especially the open tracts of prairie in this mainly wooded district, are one of the most remarkable phases of terminal drift deposition. They seem to me correlative with the commonly hilly terminal moraine belts of other drift areas.

A good description of these mounds, and discussion of their mode of formation, have been given by Mr. G. O. Rogers,* with illustrations of the probable conditions of the melting ice margin from Russell's observations of the present glaciers of Alaska. Other suggestions to account for the origin of the mounds, as by Prof. Joseph Le Conte,† who ascribed them to erosion of a formerly smooth deposit, are shown by Rogers to be inapplicable.

Passing southward from Olympia by either of the two railways, one sees the mounds of this marginal drift belt in countless numbers. The following details of the prairie areas which they occupy there and eastward were not supplied by Rogers nor Le Conte, excepting their general statements that the "mound prairies" are, as Rogers wrote, "a few miles south of Olympia," being, as Le Conte wrote, "at the southern extremity of Puget sound."

About ten miles south from Olympia, and three to five miles north of Tenino, they have given name to Rocky prairie, because of the exceedingly abundant waterworn cobbles of the gravel which forms the general prairie and also the mounds. This prairie is crossed centrally by the railway for two miles.

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* "Drift Mounds near Olympia, Washington," AMER. GEOLOGIST, vol. xi, pp. 393-399, June, 1893.

† *Proceedings of the California Academy of Sciences*, Dec. 15, 1873.

Again, one to two miles south of Tenino, Grand Mound prairie, whose eastern end is crossed by the railway, and which extends thence seven miles westward, takes its name from the same moraine mounds.

On the more western railway, running from Olympia southwest to Gate, and thence westerly to Gray's harbor these mounds are seen in great abundance on a prairie two or three miles in diameter at the distance of three to five miles northeast of Gate. Extensive gravel excavations, for ballasting the railway, have been made in the central part of this prairie, near Mima station. Several of the mounds, 2 to 3 feet high, half cut away, are seen to be through their entire thickness of the same black color as the surface soil, which elsewhere has a depth of only 4 to 6 inches; but no difference is observable in the coarseness of the gravel forming the mounds and the intervening ground. Pebbles and cobbles from 2 to 4 or 6 inches in diameter are plentiful in the mounds, on the general surface between them, and for several feet downward.

At Gate (also called Gate City) the same gravel surface is much mounded and ridged, inclosing occasional bowl-shaped depressions 2 to 5 feet deep. In a miniature degree, the contour at Gate resembles that of a typical tract of kames, which usually consist of such coarse gravel; but on the Mima prairie many hundreds of round mounds, 2 to 5 feet high, occur separate from each other, and are often very thickly grouped together.

The gradation of forms from round mounds to interlocking ridges and mounds, like small reticulated kames, debars the reference to aboriginal mound building, or to mounds of any burrowing animals, which at the first view are suggested by these very unusual drift deposits. Their true explanation has been well stated by Rogers, referring them to accumulation in little hollows of the finally very thin margin of the ice-fields when they at last melted back from this outermost tract or terminal moraine belt.

Mr. John D. Henry, of Olympia, county surveyor of Thurston county, kindly supplied outlines and descriptive notes of the several "mound prairies" of that county, including Rocky, Grand Mound, and Mima prairies, already mentioned, and Tenalquot and Yelm prairies, lying farther east, on the

railway that extends from Tenino east and northeast to Tacoma. From Mr. Henry's manuscript map of the county these prairies are mapped on plate xiii, accompanying this paper.

Grand Mound prairie beginning three miles north of the railway station of Grand Mound, and reaching thence seven miles east to where it is crossed by the railway between Tenino and Bucoda, has an immense number of gravel mounds and short ridges, from 2 or 3 feet to 10 or 15 feet in hight, often very irregularly grouped, with hollows entirely inclosed, like ordinary kames.

Tenalquot prairie, partly a grassed area, and partly covered with bushes and scattered trees, 6 to 10 miles northeast of Tenino, has many mounds, but reticulated kames there predominate, as described by Henry, rising to hights of 25 to 50 feet, with many inclosed hollows, 10 to 20 feet deep. The southeast corner of this prairie is crossed by the railway at Rainier station, about nine miles east-northeast of Tenino. Very fine views of Mt. Rainier, 40 miles east, are seen from this knolly and ridged open tract.

Four to six miles northeast of Rainier station, the railway crosses Yelm prairie, on which is Yelm station, near its center. Mr. Henry describes the west half of this prairie as having a contour of low ridges and mounds, while its east half is nearly flat but has on its southeastern edge many boulders, this being the only locality of their occurrence known to him in Thurston county.

Mapping these five "mound prairies" in a curved belt of the marginal drift, six to eight miles wide, I trace its probable continuation east and northeast in Pierce county by the occurrence of numerous lakes inclosed by the same gravel deposits, the largest being Kipowsin lake, about three miles long, trending east and northeast. The belt at the northeastern limit of my map (Plate XIII) comprises township 19 north, range 6 east, where Willis noted plentiful drift gravel ridges, knolls, and hollows, in the vicinity of the many lignite coal mines of that township, which is in an entirely wooded region.

Similarly these low kames or marginal mounds and ridges of the Puget sound ice lobe are undoubtedly traceable through all the wooded parts of this belt, not less than on its prairie tracts, where their surprising abundance has been especially ob-

served and described. Their unique phase of terminal drift accumulation is the dwarf counterpart of the great moraine hills on other areas of our late and closing Wisconsin stages of the continental glaciation.

The departure of this ice lobe was probably very rapid, like the final melting of the icefields from the areas of lake Agassiz and of the great lakes tributary to the St. Lawrence. The land had sunk from its high elevation that caused the ice accumulation, and the glacial recession uncovering this southern part of the Puget sound basin, which had then nearly its present altitude and a climate probably as warm as now, may have occupied no more than a few centuries.

Within so brief a part of the Champlain epoch, or time of land depression and final ice melting, which comprised the moraine-forming stages of waning glaciation, grandly represented in the Dakotas, Minnesota, Wisconsin, and eastward to New England, the "mound prairies" of Washington received their knolly gravel, the Steilacoom sand and gravel plains were spread in front of the retreating ice border, and the modified drift and till of the Tacoma and Seattle hills were deposited from the englacial and at last superglacial drift. The mounds, the plains, and the plateaus and hills, were successively formed or overspread by their drift, but, as I think, with no long intervals of separation, all the series being closely consecutive.

TECTONIC GEOGRAPHY OF EASTERN ASIA.

Reviews and Translations by WILLIAM HERBERT HOBBS,
Madison, Wis.

III. JAPAN. (First Paper.)

PLATE XIV.

In earlier papers of this series[1] have been treated, first, the interior plateau (*Landstaffeln*) of the Pacific coast of Asia as it has been described by von Richthofen; and, second, the significance of the eastern coast line of the continent in the view of the same writer, together with more detailed examination of Manchuria and Korea through reviews of papers by von Cholnoky and Koto. There remain for consideration the

* This journal for August and September, 1904.

chains of islands festooned along the coast, of which the more important are the Japanese chain, Formosa, the Philippines, and the Malaysian archipelago.

Both by reason of its political importance and of its detailed geological exploitation, Japan is deserving of the first consideration. The excellent groundwork laid by Edmund Naumann* and Teyokitsi Harada† have been utilized by professor Suess‡, by members of the staff of the Imperial Geological Survey.§ and especially by Baron von Richthofen in the latest of his papers‖. This latter paper for the first time makes available for the use of geologists a comprehensive physiographic and geologic structural study of the country as a whole. Its importance warrants its complete translation into English.

Edmund Naumann fixed a boundary line, his *fossa magna,* by which he separated north and south Japan. This boundary line runs in a NNW-SSE direction through the middle of the main island of Japan near its bend or "elbow." This well recognized tectonic line figures in all later geological studies of the empire. Through north Japan, lying to the east of the tectonic line, runs Naumann's *meridional chain* carrying a great number of active and extinct volcanoes. Koto had already given the name *Sachalin system* to this median line because the range of volcanoes maintains the same direction as the island of Sachalin further to the north. The physiographic divisions of Japan are thus concisely stated by Koto¶.

A mere glance at the topographic map of Japan will lead one to suppose that Hon-shu is a gigantic arc with Hokkaido and Kiu-shu at the north and south ends as the homologous appendages; and the line of the Fuji-Ogasawara volcanoes pierces right through the middle of main island. But, as geological knowledge accumulates little by little

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* EDMUND NAUMANN. Ueber den Bau und die Entstehung der japanischen Inseln. Berlin, 1885, p. 91.

† TEYOKITSI HARADA. Versuch einer tektonischen Gliederung der japanischen Inseln. Tokyo, 1888, p. 28 and map.

‡ EDUARD SUESS. Das Antlitz der Erde .Vol. ii, 1888, pp. 220-227; vol. iii, 1901, pp. 176-186.

§ Outlines of the Geology of Japan. Descriptive text to accompany the geological map of the Empire on the scale of 1 : 1,000,000, compiled by the officials of the Imperial Geological Survey of Japan. Tokyo, 1902.

‖ FERDINAND V. RICHTHOFEN. Geomorphologische Studien aus Ostasien. V. Gebirgskettungen im japanischen Bogen. Sitzungsber. d. k. p. Akad. d. Wissensch. Berlin, vols. xxxviii-xl, 1903, pp. 892-912.

¶B. KOTO. The scope of the Vulcanological Survey of Japan. Publication No. 3 of the Earthquake Investigation Committee in Foreign Languages. Tokyo, 1900, p. 15.

with time, our primitive notion comes to be largely modified; and, at present, we can say positively that north and south Japan differ in that the prevailing direction of the south is greatly influenced by the *folding axes* while that of the north is by the *meridional ruptural lines.*

The external side of North Japan, in contrast to the regular succession of geological formations of the south, consists of three tectonic blocks,—that of the Paleozoic Chichibu (Kwanto), of the Archaean Abukuma, and of the Mesozoic and Paleozoic Kitakami; and these are the gigantic *crustal* clods that bound the Pacific sea-board, each forming a geological unit, and an independent upland region. The geographical back-bone and the main water-shed of north Japan, lie, however, westwards of the discontinuous ectoperipheral zone, and is mainly built up of the *quartz-bearing tuffytes of a Tertiary age.* These remarkably constant pyroclastics constitute the foundation, through which the various andesitic lavas have welled out in *post-Tertiary times* in a nearly meridional direction, creating a long series of overtowering mighty cones.

If we were asked what is the mother-rock which supplied the material to the tuffytes, we can only say that it is the *rhyolyte* which had been poured out at the bottom of the Neogene sea, and whose derivatives, the tuffytes, had been deposited in so vast an extent as to serve for the foundation of nearly the whole of North Japan, excepting the three uplands, already mentioned."

Below I translate with few and brief omissions the text of v. Richtofen's study of Japan above cited.

* * * The study of the latter island (Yezo) has lent a new aspect to the picture. For it has shown that from its northernmost point certain lines having their origin in the geological structure stretch out southeastwards into the sea through a southwardly directed divergence, without appearing again in the following islands. The westernmost line of Sachalin is continued in the Hidaka or axial chain of Yezo, and runs likewise into the sea without recognizable continuation.

We limit ourselves here to the three large islands of Japan proper: Hondu (or Honshu), Shikoku and Kiusiu, with their small insular belongings, and the western section of Yezo with its numerous members. I, myself, have in the year 1871, when the permission to travel was rarely conferred and was difficult to obtain, visited the environs of Fuji-yama and Fusi-yama itself, made a journey along the Nakasendo straits with certain side excursions, and traveled over the island of Kiusiu. At that time the geology of the land was completely unknown.

The knowledge derived from these journeys, of the structure of the formations concerned, and many of the more important stratigraphic relations, has become of use in understanding the latter representations and the geological map.

By the comparison of the Japanese islands with the continental regions lying within the same longitudes: (Korea, Liao-tung, and north China) the striking difference makes itself apparent that upon the continent the complex of Paleozoic formations has a plateau-like posi-

TECTONIC SKETCH OF THE FUNDAMENTAL STRUCTURE OF JAPAN
(After von Richthofen)

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ASTOR, LENOX AND TILDEN FOUNDATIONS

tion, while upon the islands it occurs only compressed into folds. In the former region it is many times broken into inclined orographic blocks, and there are not lacking individual folds and bendings of the beds; but first in the Tsin-ling range begin the southwardly and south-eastwardly directed compressions or foldings which have affected all Paleozoic formations alike and which continue in the structure of all southern China. This southern part of the continent offers therefore an analogy with Japan, and it is easy to conjecture that the section of the earth which borders the great continental plateau in the south finds its continuation in the Japanese islands.

With the difference mentioned is connected a different kind of consideration. In north China the folded basement of all later deposits consists only of the Archaean formation; the superimposed cover begins with the Cambrian. In the Japanese islands on the other hand the zones and regions included in the Archaean merit special consideration, but in the basement all Paleozoic deposits are included with equal right, and first in contrast with these are the transgressing deposits and extrusions of Mesozoic and Tertiary age which are to be considered as a separate cover.

For the comprehension of the morphology this separation is important. I limit myself hence in the first place to the elucidation of the structure of the covered basement and to the tectonic disturbances which are recognizable in it, particularly with reference to the occurrence of granite and other ancient deep-seated rocks associated with it. Of little significance for the general structure are the transgressing Mesozoic formations, of predominant importance on the other hand the tectonic deformations, and the Tertiary deposits which are connected with the phenomena of vulcanism.

The present view of the structure of the Japanese islands may be briefly stated in outline. According to it the Japanese crescent or arc is a folded range of Alpine type separated into two parts by a *Graben* depression, Naumann's well known *fossa magna*. A sharply drawn line, the "median line" runs through the arc in its entire length and separates an inner zone corresponding to the core zone of the Alps marked by an abundance of granite, from an outer zone consisting of strongly folded Paleozoic sediments, in which locally also Mesozoic beds occur gently folded. In each of the two wings the two zones suffer by their approach to the *fossa* a bending back and there arises through it a kind of chain which reminds one of the Indian grouping (*Scharung*) and was compared with it by Harada, while Naumann first discovered the similarity of form but warned against the comparison. In north Japan the outer zone is formed by the ranges of Kitakami and Abukuma; their bending back occurs in the Kwanto range.

If one investigates the islands according to the present state of the detailed knowledge of them, certain essential lines which through their very simplicity corrupt the picture disappear, and with them disappears the similarity with the well known representation of the mountain crescents of Alpine type. Involved problems intrude. I turn to the

consideration in detail and fasten my attention upon the separation by the native imperial geologists into north Japan and south Japan, by which the boundary is placed in the fault cleft which limits the *fossa magna* on the west side. The results I have sought to enter upon the accompanying map. (See Plate XIV.)

A. FUNDAMENTAL STRUCTURE OF NORTH JAPAN.

On the east side of North Japan occur two elliptical mountain masses similar to each other in form but different from each other in many respects, which following Naumann's example are designated by the Japanese geologists as the Abukuma mountain region and the Kitakami mountain region.

The Abukuma mountain region forms according to Koto, who has investigated the difficult structure with care, an acute rhomboidal horst-like mountain block extending from north to south 150 kilometers in length, and 45 kilometers in average breadth. The undulating upper surface has a mean elevation of 400 meters, with an extreme elevation of 933 meters, and ascends gently toward the east from the longitudinal valley bounding it upon the west; and on the east side, 500 to 600 meters high, it falls away quite steeply upon a coastal terrace two to four kilometers broad covered by the uniform Hara steppe, which in the basement consists of Tertiary sediments and is covered with ancient coastal debris of granite blocks, sand, and gravel. The sea is now at lower levels making an attack and eroding this terrace; hence the narrow strand is accompanied by low but steep cliffs. Through depressions on the west and east side the mountain body proper raises its gently undulating upper surface as a horst. Deeply incised cross valleys have brought about a transverse division of it.

The entire mountain range consists according to Koto of Archaean rocks which fall into three divisions. The lower, designated Laurentian, consists of plutonic rocks which he has regarded as having become schistose partly through plastic and partly through rigid (firm) deformation. In the second, or Takanuki series, which consists essentially of gneissose mica schists and titanite-bearing amphibole schists, two stages are distinguished of 5,000 to 5,500 meters thickness, while the uppermost division, Gozaischo series, shows essentially amphibolytes and mica schists estimated at about 10,000 meters thickness. All strike directions are near the meridian, but always with a deviation toward the NW, hence in the mean about N by W. The same holds true for the numerous dike phenomena of ancient eruptive rocks and for the direction of the rectilinear meridional side of the rhomboid. Even if the numbers are considerably exaggerated it is yet clear that the Archaean formations are very heavy. It is, however, to be observed that the Japanese imperial geologists are inclined to identify the Gozaisho stage with their Sambagawa stage, which, to judge from its rocks, corresponds to the Wutai beds in China, that is to say, the Algonkian stage.

As a closed mass the Abukuma mountain region reaches its north limit a short distance north of the 38th parallel of latitude. Approxi-

mately 40 minutes of latitude farther to the north, but a complete degree of longitude further east the Kitakami mountain region begins, somewhat longer, somewhat higher, and somewhat broader than the above mentioned, but of similar rhomboidal to elliptical form. It consists of Paleozoic sediments, whose age, as everywhere in Japan, is with the exception of the Carboniferous part indeterminable. The strike directions of the internal structure are in general NNW to N by W, but in the southern part irregularities occur. Here a southwardly directed syncline of Trias and Jura appears; at the point of the peninsula formed by it occur also Paleozoic beds with S by W strike. Granite and other ancient eruptive rocks take part in the make-up of the Kitakami.

If the relations in age are here widely different from those of the Abukuma it is also true that differences are found in reference to the form of the coast line. In contrast to the broad Tertiary band and the even coast line of the Abukuma is found in the Kitakami an unusually well developed Rias-like projection of the coast and the absence of the Tertiary on the coast side. There the evidence of negative translation of the coast line, here the significant marks of advancing bay-like invasion of the sea into the valley outlets.

The question of the contrasting relations of these two mountain masses is decisive for the conception of North Japan. When the assigned differences in structure and constitution were still unknown, Naumann was able to arrive at the view that both masses were separated members of a continuous zone, and that the step-like pushing-out of the ridges of the northern members came about in such a manner that along a transverse line extending from Sado to Sendai a pushing out in an easterly direction of the entire northern part of North Japan in contrast to the southern had taken place. This conception determined the drawing of his median line to the west of both mountain masses, and this has, moreover, led up to the generally accepted view.

Since Abukuma has been investigated Kitakami can no longer be considered as its continuation. Both masses are much more clearly fragments of two parallel but different zones in the basement of the range, and particularly worthy of note because ancient intrusive rocks are rare in them and younger ones are almost entirely lacking. If we wish to search out the actual further course of both zones toward the north, following individually the strike direction of the fold structures of each of the two masses, we must disregard all later coverings by volcanic masses and Tertiary sediments. The places where the basement is exposed are indeed rare, but by the study of the geological map they are found to group themselves in two zones which run diagonally through North Japan in the direction N by N W to NNW. The direction of the Abukuma zone is brought out by the continuation of the parallel lines which limit the rhomboid of the Abukuma massif on the southwest and on the northeast, and which are followed also by the small ranges and the dikes of eruptive rocks in it. We come over the broad valley of the Abukuma river and find between the extended lines

the rare places where the gneiss comes up from beneath its cover. The zone reaches the west coast in the stretch in which lie the cities Sakata and Akita. To the Kitakami zone on the other hand we must refer everything which lies in the extension of its strike direction and to the eastward of the Abukuma zone. We are thus led at once over the Kitakami river. There appears still a small gneiss dome in the high Sennin-take (948 m.), which may form the boundary of the gneiss zone; but with this exception are found in the extension through all of Mutsu and beyond toward western Yezo only such formations as are referred to the Paleozoic group.

Thus the Hidaka range (upon Yezo), Kitakami, and Abukuma appear as three parallel zones of the core folded in post-Carboniferous time and striking between N by W and NNW. Their mutual connection cannot yet be made out. There are not lacking evidences of a separation through strike faults; for the above drawn profile of Abukuma indicates that Kitakami is sunk away upon its east side, and likewise at the Hidaka range the steep and short eastern descent in contrast to the gentle western slope is marked. But there enter also abnormal phenomena. For the strike of the Paleozoic sediments is in Mutsu (the northeastern part of Hondo) ENE, in western Yezo it is for the most part NE, but also in part E 10° N.

The investigations up to the present appear to give no satisfactory answer to the question where the southern continuation of the three zones lies. Hidaka strikes out toward the sea and breaks off; for Kitakami the same holds true according to Jimbo's already mentioned representation. For Abukuma it is assumed that a turning back occurs toward the Kwanto range, where the WNW direction controls everything, and that the broad alluvial bay of Tokyo conceals the intermediate members. For a conclusion the following facts may be introduced: (1) In the Abukuma mountain region it holds, so far as may be learned from the accessible writings, that the strike direction SSE to S by E. is the dominant one even to the southernmost part; (2) The Kwanto range does not consist of the Archaean gneisses of Abukuma but of Paleozoic sediments, and where on the northeast side a band of older phyllite occurs it is referred to the Algonkian Sambagawa beds; (3) In the extension of the Abukuma range to the S by E lie at the mouth of the Tonegawa the small hills of Tschoeshi made firm land through its alluvial and coast deposits. Here occur Paleozoic sediments with SSE strike and one might see in them a last outlier of a member of the Abukuma zone; (4) On the other hand there arises to the west from southern Abukuma the N-S directed Yamiso-tsukuba hill country ascending to a thousand meters which is built up essentially from Paleozoic rocks. In the north it strikes NW, in the south SW, and here it is in contact with eruptive masses metamorphosed to gneisses. These changing strike directions NW and SW are given also in the Etschigo mountains and throughout in the entire area which lies southwest from the Abukuma gneiss zone extended in our sense to the northward. It

is as if here in contrast to the former complex a regularity in bedding were not to be recognized. Only the Kwanto range appears to have an independent position. for it has, as above stated, a pronounced inner and outer side, and the Paleozoic sediments are arranged in regular synclinal and anticlinal folds.

It is clear from this that the 'median line' cannot be regarded as a separating line of two longitudinal zones of the fundamental complex. These have indeed a zonal arrangement, but in quite a different sense: the zones are cut through diagonally by the line. Undoubtedly the latter has not only for commerce but also morphologically a significance, but its origin is the result of late tectonic movements regarding which and also the volcanic lines I will speak later. I turn first to the structure of south Japan.

B. FUNDAMENTAL STRUCTURE OF SOUTH JAPAN.

In the west part of Japan, for which the little adapted name South Japan has come into use, are two longitudinal zones distinctly recognized. Here is in fact even in the basement a separating median line at hand. It follows a narrow but distinctly indicated band of mica schist generally accompanied by a band of Flysch-like Cretaceous, which runs through Kii, Shikoku, and Kiusiu with varying breadth. It belongs to the southern zone and follows it westward there also where it is far removed from the northern zone, and a small apparently neutral region in the form of a triangle is wedged between the two zones with its very acute apex in the east. To the eastward where these zones border each other the above mentioned bending back to the northward is accomplished in the face of the great transverse fault along the Fuji line.

The two zones offer in scenery and in structure noticeable differences. Their relation to each other is one of the keys for the explanation of the problematical structure of Japan. We must therefore consider them in detail.

THE NORTH ZONE. This is separated into a western part as far as the narrow neck of land between the Wakasa gulf and the Owari bay, and an eastern part from there to the great cross fracture. To the first mentioned belong: Tschigoku (in somewhat extended sense), that is to say, the great western peninsula of Hondo which extended to the eastern shore of the Biwa lake is 510 kilometers in length; the neck of the Kii peninsula to the mica schist band; the eastern and middle interior sea with its islands and the two northern peninsulas of Tschigoku; in addition the northern projection of Kiusiu. The eastern portion embraces in addition to a little region in the southeast the rest of the country between Biwa lake and the great cross fracture.

In Tschigoku appear in the fundamental complex schistose and quartzitic sedimentary rocks which are regarded as Paleozoic. They strike in general parallel to the peninsula, that [illegible] about W to E and W by S to E by N. The rectilinear stretch o[illegible]t line facing Korea directed from SW to NE from Yamatu, I[illegible]ami and Idsumo, is

a steep diagonal fracture on which the beds with the above mentioned strike disappear, and does not therefore indicate how one could conjecture from the contours a bending of the internal structure or of the entire mountain member. Far more character-giving than the sedimentary rocks is widely distributed hill country of deeply decomposed granite which on the surface is disintegrated to gruss, which also composes almost without exception the islands of the interior sea and the northern peninsula of Tschigoku. To the eastward are inserted two bands of gneiss, on the border injected by granite, a broad one entirely in the south in connection with the band of mica schist, a narrow one in the north. Both include a middle band of Paleozoic sediments varying by 100 kilometers in its breadth.

Beginning about at the 136th meridian there enters quite gradually a southeasterly convex bending in which all three bands take part. The gneiss band in the neck of the Kii peninsula, although according to the conception of the Geological Survey divided into three meridional horsts, strikes first W to E and turns then a little toward NE. The middle strip shows still in the vicinity of Gifu W-E direction with local deviations. But in this are found many irregularities.

To the east of the Owari bay the bending proceeds rapidly, the strike in the southern gneiss band becomes NE, and west from the upper Tenriu-gawa N by E. Also the northern gneiss band belonging to the regions of Hida and Yetschiu shows in the strike of its beds the same bending over NE to NNE. This is the bending back of the north zone clearly recognized by Naumann.

Deviating from it is the occurrence of granite. To the traveler, as well as to the one who glances at the geological map, the great rôle which this rock plays, as well in the horizontal distribution as in the upward extension to great altitudes, is most striking within these eastern portions of the north zone. For granite plays the principal part in the composition of the mighty chains of the Kisso and Hida ranges. Both are directed to the NNE; but the latter bends in the stretch indicated to the meridional direction through Otendjo-yama (3185 m.), Tate-yama (2936 m.), and Renge-yama (2934 m.). From the island Awadji the granite follows for the most part lines which do not correspond with the strike direction of the fundamental complex, but intersect it and in a certain degree anticipate its bending. The direction NE is taken by the granite where the schists are still directed from W to E; and where the latter turn toward the NE and NNE the lines of the granite have directions N, N by W, and NNW. The arrangement can be considered as an irregularly radial one in the arc which is convex to the SE. * * * * *

Another phenomena may be referred to the stretching and consequent opening of the texture of the outer portions of the zone. This is the dismembering which it has there suffered. It is in contrast with the simple coast line of the north side and the compressed structure which distinguishes the Tamba plateau and the mountainous country of Mino-Hida. It is sufficient to bear in mind

the invasion of the sea in numerous bays, like the Owari bay, and the many bays united in the interior sea, Seto-Utschi, or the mentioned dismemberment of the gneiss zone of the Kii peninsula into four horsts, separated by meridional *Graben*. All these phenomena belong exclusively to the outer portion of the north zone and terminate sharply where they join the south zone.

THE SOUTH ZONE. The above mentioned arms of the sea are all sharply cut off in a line by the above named and even narrow band of steeply inclined mica schists, which were referred to the Samba-gawa stage, accompanied as they are by a narrow band of Flysch which runs through the islands Kiusiu, Shikoku, and Kii. Furrows of slight breadth are incised and serve the ocean as portals for connection with the wide bays of the north zone; they are kept open by powerful tidal currents. The south zone begins at these portals. It has already been shown how this zone enters in considerable breadth from the west as the presumptive continuation of the south Chinese mountain country and consists of Paleozoic deposits belonging to the Japanese Chichibu system, which are disposed in steep SW to NE striking folds. The dominance of northwestern dip is indicative of compression from the NW. I have in the place mentioned given to the still nameless range, the name Kuma range, after the Kuma river, and sketched it as a nearly uniformly high mountain country, difficult of access and deeply incised by meandering streams. It has also been shown how the entire zone inclusive of the mica schist has suffered gentle bending and enters the island of Shikoku with E to NE strike, crosses it entirely and continuses toward the peninsula of Kii, by which the strike gradually changes into W by S, E by N, and WE. On the way through Shikoku and Kii the compression of the structure increases with the closeness of the folding, and with it the altitude increases; the mountain country becomes more difficultly accessible, more closed to travel, and is thinly populated; the valleys are more deeply intrenched; waterfalls occur in the meandering channels of the brooks. This mountainous country of Kuma-Kii, as it may here be called, separated into individual fragments but belonging together, stands in striking contrast with the landscapes of the north zone, which are distinguished by rich variety of topography,

For the comprehension of the morphology this separation is important. I limit myself hence in the first place to the elucidation of the structure of the uncovered basement and to the tectonic disturbances which and, with the exception of the highly elevated eastern portion, by easy communications and great capacity for settlement, hence by dense population and an abundance of cities. Upon the geological map, the contrast is marked in the concentration of granite in the north zone until almost upon the border, where it is cut off and it is a rare occurrence in the mountainous country of Kuma-Kii: likewise the broad band of gneiss of the north zone ends sharply upon the rectilinear border. The general map shows that the criteria of open structure which characterize the southern part of the north zone, and in part the basins of the inland sea, and the gneiss horsts of Kii, never extend into the south

zone. The connections of the seas are made through gaps in it; but these have an entirely different character. The coasts within the south zone are in part of pronounced Rias-type, where the sea washes directly the transverse ends of the bedded rocks, and in part gently arched steep coasts which indicate falling in. Volcanoes are lacking with the exception of those in the Liukiu line.

From the general morphological point of view, it is significant that the line of the mountainous country of Kuma-Kii (which up to the emergence from Kii has a length of 690 kilometers) is the *unique example* in the entire system of arcs here coming under consideration, *of an arc which is convex to the ocean.* With it is connected the rare phenomenon that the compressive force has been directed from the convex toward the concave side of the arc. One can designate this as *a reverse arc of compression.*

CONTINUATION OF THE TSINLING RANGE IN JAPAN. This result of finding a relation in the same sense and of the same kind in Japan and China is based upon the conception, already expressed, that Tschiugoku, with the ranges of the interior sea, is the continuation of the Chinese Tsinling range, which disappears suddenly at the Honan fracture. The comparison of the structure says nothing against it; for in China also zones of gneiss alternate with those of Paleozoic beds, and post-Carboniferous granites play an important rôle. Both are alike the expressions of the important compression of the entire mountain mass toward the south. To the argument which Naumann derived for the compression of the Japanese range out of the northerly bending of the eastern end, is added that common to China of the arc-like compression of the ranges in the country to the south. The separation of the Japanese fragment from the Chinese by an interval of 16 deg. of longitude is indeed important; but on the one hand there appears to be present within the intervening space in the Hwai range a notable depressed fragment of the same range thrust still farther southwards and against the Tsinling range, and on the other hand, the interior region is one of very deep-seated tectonic disturbances. It cannot be assumed that such a mighty framework in the structure of the earth's crust as the Tsinling range with its western continuations in central Asia from the time of its formation on, has come to so sudden an end; it is far more probable that it has had a still further continuation in the direction of the present Pacific ocean. Here in Japan it comes once more to the surface with somewhat altered direction, after which, then, in the vicinity of the most extensive of the present extreme depressions of the oceanic basin, it seems to come actually to an end. This gives to the study of the structure of Japan increased interest.

THE NAGASAKI TRIANGLE. If the view here introduced is correct that only the northwestern part of Kiusiu, with the granite mountain country of Sefuri (1030 m.), belongs to the north zone, there remains between this and the south zone a triangular area which is bounded on the north side by an E-W line (Matsuyama-Kuruma-Imari) and on the

south by the connecting line Matsuyama-Yatsuschiro. The apex in Matsuyama lies opposite the stretch of coast between Imari and Yatsuschiro as base with unique variety of its lines and the types of its landscapes, in which Nagasaki is the place generally best known. As has already been stated, a basement visible only in few places, owing to erosion and subsequent deposition, consists here of probably Archaean schists, among them mica schist; and rock otherwise almost foreign to the north zone, is very widely developed along with gneiss, while granite occurs only in subordinate amount. Harada considered this region as a continuation of the lower zone, which belongs to the interior sea. In that case, it would be a portion of the north zone, and it would be necessary to assume that this suffers a deflection toward the SW. The interior strike of the beds must then show this deflection in western Tschiugoku; but I have found no observation which would confirm this. The position of the intermediate members must, therefore, still remain uncertain.

For this space the great development of volcanoes is characteristic. Aso-yama, Unsen-yama, Tara-dake, and others, whose activity in part still remains, have covered the land over a wide extent with lava and ash.

"THE AKAISCHI RANGE. The remarkable position of this high and for the most part massive mountain block was first recognized by Naumann; further investigations have confirmed his view. The fold axes of the Kuma-Kii, and its accompanying band of mica schist, run from the peninsula of Kii over the entrance of the Owari (or Ise) bays, toward the lower course of Tenriu-gawa. Here begins a peculiar line, directed toward the Suwa lake, drawn to the eastward of the middle and upper course of the last mentioned river and parallel to it, which marks the line orographically and tectonically. It follows sharply for 85 kilometers the direction N 18 deg. E and turns beyond the pass Jiro-Toge in a further stretch of 43 kilometers, in a direction N 10 deg. E. Along it runs a furrow, distinguished by short rectangular water courses, breaking through westward to the Tenriu-gawa, several passes, and numerous villages. It separates gneiss with granite in the west, from Paleozoic mountains with bands of mica schist on the east. There the north zone is sharply bent to the NNE and N by E; here a similarly deflected mountain fragment which all observers including Naumann have recognized as a fragment of the south zone, that is to say, of the Kuma-Kii range. Naumann has called it the *Akaischi sphenoid.* This mountain block has much compressed structure, reaches in Akaischi and Schirane altitudes of 3,093 and 3,150 meters, and has a meridional extension of 110 to 130 kilometers, with a medium breadth of 40 kilometers.

It shows that there where the north zone has suffered the strongest deflection of its crest through its compression toward the south, an opening of the correspondingly bent Kuma-Kii range has occurred in places until it has disappeared, and an almost detached fragment of it has been thrust in the meridional direction. If one regards the region

of the Suwa lake as the fulcrum in the turning of this Akaischi mountain block, then it is easy to surmise that the connecting line between it and Yatsuschiro in Kiusiu is in accord as a likewise scarcely moved point approximating to the original course of the north border of the south zone. It runs somewhat south of Matsu-yama, touches Kioto, and has the direction of the average sinian strike. If one compares with it the present position of the band of mica schist, one derives from it approximately the amount of deformation that has occurred.

(To be continued.)

THE UNTENABLENESS OF THE NEBULAR THEORY.

By N. Mistockles, Minneapolis, Minn.

I.

"There was once a time when the earth was distended on all sides away out to the moon and beyond it, so that the matter now contained in the moon was then a part of our equatorial zone. And at a still remoter date in the past, the mass of the sun was diffused in every direction beyond the orbit of Neptune, and no planet had any individual existence, for all were indistinguishable parts of the solar mass. At the period where the question is taken up by Laplace's treatment of the *nebular theory*, the shape of this mass is regarded as spheroidal." (John Fiske, The Unseen World, p. 7.)

To readers, who are interested in cosmogony and who have acquainted themselves with the works of Kant, Laplace, Herbert Spencer, and John Fiske, it may, perhaps, seem like lost labor trying to find flaws in and pronounce untenable, a theory which was advanced by the two former and, on the whole, accepted and defended by the two latter. Still, everyone must admit, that a theory, which pretends to explain any natural phenomenon, but leaves both its essence and qualities in general unexplained, is highly unsatisfactory and not to be depended upon. The nebular theory* can, consequently, not command belief so long as the phenomena and natural forces, which it has taken upon itself to interpret, practically remain a mystery. This failure on the part of that theory proves it conclusively to be erroneous. Nor is there any risk in asserting

*The term *Nebular Theory* is, in this treatise, considered more proper than *Nebular Hypothesis*, and is treated as an elaborated theory, which the well-known Nebular Hypothesis is in the full meaning of the word. The Nebular Hypothesis is also often spoken of as a theory, even by authorities, and among others John Fiske has accepted it as such, which is shown in the quotation given above.

that errors may be found where we know beforehand that they exist.

We gladly admit, however, that our sincere thanks are due the modern philosophers for so insistently recommending the study and application of the science of logic; and for their telling us, that we can never gain a clear and comprehensive understanding of any subject except by means of logical thinking and harmonious and consistent reasoning. "Logic," says John Fiske, "is to the scientific investigator what the law of proof is to the lawyer."

This is true, and it is, furthermore, of vital importance for our discussion of the theory in question. But logic alone is not sufficient. Let us, therefore, before we take up the problems before us, add a few observations concerning certain rules, which every student of natural laws and forces must recognize and observe.

However important and indispensable logic is to a scientific investigator, it can, nevertheless, serve only as a valuable assistant under certain conditions. As one of these conditions, may be mentioned a thorough and complete knowledge of the starting point from which one, by means of induction, seeks the solution of a problem. No matter how logically one may reason, if the first conclusion regarding the condition, essence or genesis of a thing is wrong, every subsequent conclusion, based on the first, will lead from error to error ad infinitum. It is the non-observance of this fact, as we shall show later, that has led the natural scientists to commit their greatest errors. They have been logical to the tips of their fingers, but, in many instances, totally blind as to the proper conditions for the use of logic. Thus we often find, that no distinction is made between a philosophical and a mathematical problem; and we are told at times, that this or that scientist has solved mathematically a much discussed problem in spite of the fact that that same problem does not admit of a mathematical solution. A philosophical problem cannot be solved by mathematics; for mathematics can give us a trustworthy result only when all the elements and parts of the subject are distinguished and understood in all their details. The cubic contents of a hill and its elevation above the sea level, for instance, is a geometrical and, hence, a mathematical problem; but the

genesis and formation of that same hill is a philosophical and geological problem which cannot be solved by computation. Consequently, when we are told that a philosophical problem has been mathematically solved, as for instance, when G. H. Darwin "proves" by mathematics that the moon almost touched the earth's surface some 50 or 100 million years ago, and that it revolved around the earth in about four days, then we must remember, that such speculation is simply an illusion. To give a rational solution of such a problem lies wholly outside the province of mathematics as we shall show more clearly in §13, when we come to speak of the true origin of the planets.

Next to and in connection with a clear understanding and a correct conception of the starting point, all sound inductive reasoning requires an equally thorough knowledge of all complications and conditions that may arise later in the course of reasoning; for logic, we must remember, can serve only as an aid or means, like a horse or a ship, which goes wherever we guide it. A navigator, for example, who sails from New York, bound for Liverpool, but lands in Porto Rico, gains little by claiming that Porto Rico or any part thereof is Liverpool, because the ship brought him there. Thus it is also with the mathematician and the philosopher. The result gained is not a sufficient guarantee for the correctness of their reasoning; because where due attention is not paid to nature and those of its laws that bear upon the problem, the result might so easily be "Porto Rico" instead of "Liverpool."

Now, therefore, it is clear that one, who attempts to explain the origin of the solar system by means of the nebular theory, must necessarily, in the first place, have a correct conception of the principal forces involved in his theory as a condition for a correct understanding of the genesis or origin of the heavenly bodies, this to serve as a starting point on the basis of which he afterwards, by the aid of logic, tries to explain the nature and inner relations of the whole system.

Let us, then, remember this as we now proceed to the discussion of the nebular theory; and let us remember also, that it is our duty to satisfy all reasonable demands which the principles we have laid down, make upon us as we proceed, step by step.

2. The nebular theory, as elaborated by Laplace, and before him presented in several of its main features by Immanuel Kant is, in brief, as follows:

All the heavenly bodies, large and small, which compose the entire present solar system, have originated from a common, vast nebula. This nebula was spherical in form and filled space as far as to the orbit of the most distant planet. The mass composing this nebula contracted towards the center; by this contraction, rotation and heat were generated. As the contraction and consequent condensation went on, the rotation increased, which again caused an expansion in the equatorial region and depressions at the poles. On account of the rapid rotation the centrifugal force finally increased to such a degree that it overcame the force of contraction. This, again, caused the separation of a portion of the nebula at the equator, which portion continued to revolve around the nebular mother in the form of a ring. This operation reoccurred as often as the rotation increased to such a degree, that the centrifugal force overcame the centripetal or inward tending force. Thus one ring after another was formed; and in time these rings broke, contracted, and formed themselves into individual nebulae, all rotating and revolving around the common center of gravity. These new bodies, in their turn, threw off rings, which, like the former, became spherical nebulae. The former became the planets; the latter the moons of the planets, while the original and constantly contracting nebula—finally forming into a mass of glowing lava—became the Sun and center of the system.

The cause which led to the construction of and subsequent adherence to the nebular theory, was the wonderful symmetry of the solar system. The advocates of this theory noticed that the planets revolve in analogous orbits around the equator of the Sun whose plane of rotation thus becomes identical with the orbits of the planets. They found also, that the same relations exist between the planets and their moons, so that the moons revolve around the equator of the planets, and that the plane of the planet's rotation thus coincides with the orbits of the moons, or nearly so. The object of the nebular theory, thus, is to explain how the whole solar system was originally formed and put in motion, and how the order and motion of its various parts have since been retained and preserved. The

adherents of that theory have not, however, been able to find any sufficient cause for the rotation of the nebula. This is important; for the nebula must of necessity rotate in order to form and throw off rings. They supposed that this cause could not possibly be any other than the contraction of the nebular mass, which was taken for granted and assumed to be a fact.

Herbert Spencer and John Fiske have dwelt with great delight on this point and claimed that nothing can be imagined more clearly proven and demonstrated. They have pointed out, that according to the theory in question the planets Jupiter and Saturn must rotate very rapidly on account of their vast mass and powerful gravity; and which they think the observations prove to be true. They have pointed out further, that said planets must for the same reason have thrown off many rings, and, consequently, have many moons, which the observations also prove to be correct. This view is, therefore, in the words of Herbert Spencer, incontrovertible.

We shall now take up these premises and conclusions one by one and see whether we can not derive these same phenomena from other sources. Perhaps we may find some other methods than those mentioned above, by means of which we may be able to explain why the planets move in orbits analogous to the plane of the solar equator; and likewise we may detect another cause for the corresponding state of things in regard to the moons and planets; and hence we may possibly discover another manner than that set forth in the nebular theory, in which the moons have come to the planets.

The last mentioned of these investigations we cannot undertake immediately, however, as that would carry us too far from our main subject at present. Let us rather begin with the fundamental point in the theory, the starting point, and return to the numerous details later on.

§3. The nebula, then must have rotated; and there is no reason to doubt that it did. But let us remember that the vital point right here is to determine *what* caused the rotation. The importance of this point is further emphasized by the fact that the same force must later on serve as the motive power for the rotation of all the bodies formed from the original nebula.

How the rotation of a nebula is caused by the contraction and condensation of its mass, can, according to Herbert Spencer, be explained in the following manner:

"Each portion of such vapor-like matter must begin to move toward the common center of gravity. The tractive forces which would of themselves carry it in a straight line to the center of gravity are opposed by the resistant forces of the medium through which it is drawn. The direction of movement must be the resultant of these—a resultant which, in consequence of the unsymmetrical form of the flocculus, must be a curve directed, not to the center of gravity, but toward one side of it. And it may be readily shown that in an aggregation of such flocculi, severally thus moving, there must, by composition of forces, eventually result a rotation of the whole nebula in one direction." (First Principles, p. 198, §76.)

To a merely casual observer this may, perhaps, seem reasonable and many may consider it tolerably satisfactory. Let us not, however, be satisfied with this superficial probability, but analyze the statement and thus determine to what an extent it is reasonable.

It assumes that it is the force of gravity which first set the matter in motion and which afterwards continued to cause this motion or rotation. As the nebulous mass contracts and condenses, the attracted parts meet resistant forces in a supposed medium through which they must pass, the result of which is a curved motion to one side instead of a motion in a straight line towards the center.

Here we notice at once a most remarkable circumstance, which has been left unexplained, but which nevertheless, is of great importance, namely, that the medium through which the attracted *parts* must pass does not move in consequence of the vapor-like or gaseous condition of the nebula. Why does not this *medium move together with the vapor*, sinking towards the center?

This medium cannot be supposed to offer a resistance similar to the resistance offered by atmospheric air to objects passing through it, for the nebula itself, according to Laplace, was thin as air long after the rotation commenced. To suppose such a resisting medium in the nebular matter in that stage of evolution, would be the same as to suppose that air in

motion would meet within itself a resisting force which would change the direction of the motion. Such a supposition would be contrary to both nature and reason, and still the rotation of the primeval nebula of the solar system as the theorists have imagined it, depended upon just such supposed conditions; and hence we find that the very starting point of the theory rests on a rather shaky foundation.

We notice, next, a point of equal importance, namely, that the strength of the resisting force, supposing that it exists, would be proportional to the velocity with which the attracted matter passes towards the center; and further, that this velocity would be entirely too small to create the necessary resistance! This presents a new difficulty and raises a new doubt; if the condensation of the matter, in the condition of a nebula at such a stage, is not sufficiently rapid to create the necessary resistance, then its rotation would thereby be prevented.

Let us accept the assumption, however, that the contracting matter meets a resisting force and that the condensation is rapid enough to cause a resistance strong enough to change the course of the contracting matter, and see if that puts us in a better position to accept the theory, or, in other words, if it then will be natural to suppose that this change in motion be from a straight to a curved line, to one side of the center more than to the other.

When we speak of a nebula whose matter is condensing, we claim at the same time, that the force of condensation and the force of resistance are identical in all directions to and from the common center of gravity, whereby any motion towards one side becomes just as possible or impossible as a motion towards the other side. From this we must conclude, that rotation cannot possibly be caused in that manner. If in spite of this, we hold on to the supposition claiming that the nebula rotates around its center by virtue of the force of gravity, then we must at all events admit, that the rotary motion could take place in a plane in one direction as well as in another, since the attractive force is the same in all directions. The rotation should, then, according to the theory of this generative, rotary force, have exactly the same cause to go from south to north, from north to south, from east to west as from west to

east. We would expect that Herbert Spencer and other philosophers should have understood this!

Here we may safely conclude that the rotation of a nebula cannot be caused in the manner that this theory claims; still it may be interesting to consider, in this connection, some of the other consequences resulting from that hypothesis.

The ethereal matter, as we may most properly call it, through which the nebular stuff, attracted towards the center, must pass, and the resistance developed by this motion, must necessarily be the same, no matter in what direction the motion takes place, since it is the motion itself which creates the resistance. A motion towards the side of the center must, therefore, meet the same resistance as the one moving straight towards the center. Since the resistance, thus, will be the same, no matter in what direction the nebular stuff is moving, we are forced to conclude, that its motion in any other direction than that determined by the law of gravity, is as impossible as for water to run up hill.

We shall find, further, if we accept the hypothesis in question, that the resistance which was a consequence of the contraction and sinking of the matter, was coexisting only with the medium which caused it. Now, then, if we direct our attention to fully condensed and encrusted bodies, as for example the earth, we cannot escape the impression that here, at least, the above mentioned medium must long ago have ceased to exist as a means of resistance to the contracting matter; for the contraction has practically stopped. In regard to the Earth, we can, consequently, not speak of any rotation of matter around the center; hence the Earth itself should not rotate, but it does rotate, nevertheless, and with a speed of about 17 miles a minute.

In the discussion of this theory, to which many of the astronomers still cling, it is also of great importance to call attention to the fact, that planets of about the same size ought to rotate with about the same velocity, with this difference, that a younger one ought to rotate faster than an older one, and that the Sun, which, it is claimed, is still a glowing mass, should rotate faster than any of the planets. Venus, which, accor -ing to the nebular hypothesis, is younger than the Earth, should, consequently, surpass this body in the rapidity of its

rotation. But it is now admitted the world over and especially verified by Schiaparelli's observations, that Venus is practically devoid of rotation, turning on its axis only once in every anomalistic period, 224 days.

This is another rock in the seaway of the nebular theory which cannot be gotten past. According to this hypothesis, we have a right to assume, that the same processes which are going on in the interior of the Earth, are operating, at least in a comparative degree, in Venus also; and if the contraction has originated and sustained the Earth's rotation, then Venus also ought to rotate, but it does not.

If we, however, should persist in the supposition that Jupiter's violent rotation is caused by an interior powerful rush of matter around its center on account of its gigantic size, what should we then believe and say about the Sun, which is 1000 times larger than Jupiter and in a state of far more intense heat, and still it swings around on its axis only once for every 60 of Jupiter's rotations?

It is clearly evident from first to last, that contraction or condensation has absolutely nothing to do with rotation and that the theory, which claims that it has, is without foundation in all of its premises. It follows likewise, that the conclusion, that the rapid rotation and numerous moons of Jupiter and Saturn should prove that the rotation is caused by the contraction and heat of the matter, is erroneous and false.

Further on we shall show what the real causes are for the intense rotation and numerous moons of the mentioned planets, and our proofs shall be clear and convincing to all. But before we do this, other matters claim our attention. Our final observation upon the subject, so far as it has now been discussed, is, that the reason put forth as to the cause of the rotation of the heavenly bodies, is, to say the least, meaningless.

§4. Let us now turn from the discussion of the nebula's rotation and its other qualities, which we have touched upon, and pay attention to another proposition, namely: Is it natural and reasonable to suppose, that such a nebula, as the nebular hypothesis proposes, ever existed in reality? We may suppose that Neptune is the most distant planet in the solar system, and the size of the original nebula was determined by the orbit of this planet. Out of this originally spherical misty mass the

Sun and the planets are said to have been formed. Consequently the solar system in its present state represents the matter which composed the original nebula. If we, then, should find by thorough investigation, that the Sun and the planets together contain, say about only half of the matter which the original nebula contained, then the theoretical supposition would be a miserable failure. The question is: What was the density of the nebular matter? In order to clear this point, we must know the size and cubic contents of the nebula and thereby its weight; and then compare this weight with the weight of the Sun and the planets together, which is known.

In the first place, then, it seems proper for us to inquire whether, if the Sun and planets were dissolved into atoms and spread out evenly in a space having a diameter of 5000 million miles it would constitute a mass dense enough to be heated by the friction of its own matter and having depressions at the poles and expansion at the equator, together with an immense centrifugal force, sufficient to throw off rings?

Francis P. Leavenworth, professor of astronomy in the University of Minnesota, told me, that one of his students had worked on this problem and figured out, that if our solar system were dissolved into atoms and spread out evenly in a comparatively spherical space, filling the orbit of Neptune, these atoms would be hovering about, separated from one another by large distances. Professor Leavenworth himself said that this was no doubt correct. But if that is so, which it evidently is, what, then, becomes of the attribute, which the theorists have ascribed to this misty mass, which would be no mist, but rarer than high mountain air? It follows, also, that it would have neither equator nor poles, neither rotation nor centrifugal force, and far less would it throw off any rings!

We notice at once, that the assumption with regard to the size of the nebula is just as erroneous as we have before found the assumption with regard to its rotation. Let us, however, at this point, consider the nebula from another point of view.

As a consequence of the attributes ascribed to it, such as heat, centrifugal force, expanded equator, and flattened poles, it ought to have possessed a considerable density. Let us suppose, however, that it had the density of common air only, a supposition which every one must admit to be fair. In order

to find the weight of its mass, we must find its cubic contents and then multiply that by the weight of air, which is 815 times less than that of water.

We have already stated, that when the planet Neptune was formed, the size of the nebula must have been limited by his orbit. Now, since the diameter of Neptune's orbit is 5528 million English miles, that must also have been the diameter of the nebula at that time. It is difficult to determine accurately the polar depressions, which are said to have been considerable, as we have already noticed. We have hardly any reason to suppose, however, that the depression at both poles was greater than one third of the equatorial diameter. But if it were possible to suppose these depressions to be larger, let us, for safety's sake, square off the curvature on all sides of the nebula and assume its mass to be equal to that contained by a cube whose sides were only 3,500 million miles. This figure must then be multiplied by itself and the product of 3,500 million in order to find the quantity we seek in cubic miles.

The product which is to be multiplied by 3,500 million we find to be 12 quintillions and 250 quadrillions and this sum multiplied by 3,500 million gives 40 octillions, and 875 septillions, which represents the contents of the nebula in cubic miles.

In order to make this immense number a little more conceivable, let us remark, that one such cubic mile contains 254,-358,061,056,000 cubic inches, and that the Earth contains 260,-000,000,000 cubic miles, which makes 66 septillion cubic inches. The nebula would, consequently, contain 619 times as many cubic miles as the Earth contains cubic inches.

Now, since air is 815 times lighter than water, and a cubic mile of water weighs 410 million tons, then a cubic mile of air must weigh 815 times less, or 503,067 tons. In order to find the weight of the nebular mass, we must then multiply its number of cubic miles by 503,067.

This multiplication brings us to the highest power of notation: 21 decillion and nearly 560 nonillion tons. The combined weight of the Sun and the planets, according to modern astronomy, is 2 octillion and 18 septillion tons. Hence the

surprising result: The nebula outweighed the whole solar system ten million times!

We are, indeed, forced to admit that such a nebula could not possibly have existed, and that the solar system must have had a different origin than that accepted by the theory under consideration.

§5. If we should assume the existence of such a misty body, rotating rapidly and possessing immense centrifugal force, it becomes a matter of importance to pay particular attention to the peculiar circumstance, that the centrifugal force separated the equatorial belt of the rotating sphere in the form of colossal rings.

We have already noticed, that the theorists claim as a reason and law for this peculiarity, that the nebula rotated by virtue of the contraction of its matter and that it threw off rings whenever the centrifugal force exceeded the centripetal, or the force tending towards the center. Contraction or the downward pressure, is, as we all know, occasioned by the force of gravity. Now, when a centrifugal force is assumed, which overcomes the centripetal or—which amounts to the same thing—the force of gravity, then the question arises: By what means did the nebula rotate during the periods when that force was overcome or neutralized, which according to the first assumption was the cause of the rotation and the origin and support of the centrifugal force?

Here is torn down with one hand what is built up with the other. If it is claimed, that the centripetal force or the consequences thereof, causes the rotation, then it is thereby denied that the resulting centrifugal force can neutralize the centripetal; for then it would also neutralize the rotation and the centrifugal force itself. If, on the other hand, it is claimed that the centrifugal force can neutralize the centripetal, then the same assertion overthrows the theory about the origin of the centrifugal force.

When we thus find that the hypothesis offered as an explanation of the rotation overthrows the hypothesis advanced as an explanation of the formation of the rings, and, likewise, the latter to overthrow the former, then it is also evident, that the theory, depending upon the harmony between

these hypotheses, finds itself in a dilemma, from which it cannot extricate itself.

§6. From the theory that rings were formed every time the centrifugal force overcame the centripetal, it follows, that the rotation which created the centrifugal force, was oscillating since the centrifugal force itself was varying and irregular. When the same theory further advocates that the rotation is a result of the contraction which, again, is a result of gravitation, then the gravitation itself must have been oscillating, that is, increased and decreased alternately, since all its results were oscillating. At the same time it is held, that the force of gravity in a certain mass is fixed and unchangeable. It follows, consequently, that neither the gravity nor the rotation, caused by said natural force, could be oscillating, from which follows further, that the centrifugal force neither can be nor has been oscillating. The theory about the formation of rings is, thus, also at this point, absurd in the extreme, since it assumes said formation to be possible, only by supposing a variable rotation, due to a variable gravity of the nebular mass.

We find, thus, that what is said in one sentence is contradicted in the next.

§7. We have already shown, that the rotation of a nebula is independent of the condensation of its matter and the resistance with which this meets. A new question arises, therefore, in connection with this very subject, namely this: Would it be in harmony with the laws of nature to suppose that the centrifugal force, leaving out of question how the rotation was caused, could have expanded the equator of the nebula so as to rid it of those rings?

Let us call particular attention to the fact, that even if the rotation of a heavenly body be assumed with a speed so tremendous as to satisfy any hypothesis-maker, say a thousand miles a second or so, there would even then be no detachment of matter from the rotating body, because of the fact, that the natural result of such a rotation would be an expansion and solution of the whole mass into a gaseous state with every particle of matter continually subjected in an equal degree, to the central force of gravity of the rotating mass.

It matters not, then, in what way a reaction in the movement of rotation would be caused. The simultaneous contraction of the nebular matter, as the rotation decreased, would, in consequence of the fact that the force of gravity acted alike upon every component part of the gaseous body, be the same for every part and particle, and proportional to the weakening of the centrifugal force.

In a heavenly body, the centripetal force is its spirit of gravity and its power of cohesion. The centrifugal force, on the other hand, is a mechanical result of the rotation of the same body. Hence, since the first is the cause or ground of the second, it follows, that the second cannot suspend the first either for a short or a longer period. To say that the centrifugal force, under these conditions, would be able to throw off rings from the nebula, is identical with saying that a man could stretch out his arm with such force that it would be severed from his body. In both cases, the fact is overlooked, that the mechanical and outward working power is dependent on the body's power of cohesion.

But even if, at this point, we would close our eyes to the fact that a magnetic attraction cannot be suspended or reduced by a mechanical power, we must at least admit, that the influence of the centrifugal force in the interior of the Earth, where it operates against the centripetal force, cannot be subjected to experiments or artificial presentations. Its influence cannot be demonstrated in any other way than to present it as co-operating with the centripetal force, which is impossible since everything on the earth's surface is dependent on the earth's attraction, from which follows that an artificial center of gravity, as a condition for the centripetal force, cannot be made.

It is said that physicists have demonstrated by means of experiments, that a rotating nebula must develop and throw off rings, and hence that the assumption accepted and defended by the believers in the nebular theory is in accordance with the laws of nature. Now this reasoning is not quite scientific. Any one, and especially a philosopher, ought to understand, that a demonstration of that kind demands that such an artificially constructed nebula must possess a center of gravity and centripetal force in order to indicate by its rotation and cen-

trifugal mechanism the real nature and qualities of a cosmic nebula.

When these theorists, nevertheless, claim that they can demonstrate the nature and centrifugal force of a real nebula by means of an artificial nebula, which lacks centripetal force and cohesive power, then we are forced to shake our heads: the whole device is overwhelmingly ridiculous.

§8. It is evident that Laplace thought of Saturn's rings in developing his theory about the solar system. He looked upon these rings as equatorial formations caused by the centrifugal force and on the way to make a moon or moons, and also that the already existing moons of this system had been formed in the same manner from rings thrown off long ago. He believes, thus, that the planets themselves had at some distant time been formed from rings of a nebula; and that Saturn tells, as it were, the story of the creation of the solar system.

Since this planet played so important a part in Laplace's investigations, as well as in the speculations of the adherents and defenders of his theory, it may be well to take up that matter in particular right here and investigate it a little closer.

We notice, then, first of all, that no other explanation of the origin of Saturn's rings, except the one offered by the nebular theory has been generally accepted. Further, that if some other explanation can be made acceptable, that will also necessitate some other explanation of the origin of Saturn's moons, and likewise of the planets, the result of which will be the overthrow of the original theory also at this point.

If a nebula be imagined to throw off rings by virtue of the centrifugal force, then the breadth and thickness of the rings must stand in a certain relation to the size of the nebula. If we, then, think of the original nebula, we understand at once, that its rings must have stood in somewhat the same relation to it, as for example, the rings of Saturn stand to Saturn. What is that relation?

Saturn's diameter has been found to be 76,000 miles, and the total width of the rings together with the distances between them, 37,000 miles. The thickness of the rings is very small and is supposed to be from 50 to 100 miles. It is possible that they are much thicker, but let us say that their thickness is only fifty miles. Now, if we divide the diameter

of the plant by the thickness of the rings, we find that the latter is 1/1520 of the former. Further, since we have found the equatorial diameter of the nebula to have been 5,528,000,000, miles, it follows that the ring out of which Neptune was formed must have had a thickness corresponding to at least 1/1520 of 5,528,000,000, which is 3,636,842 miles or about four times the diameter of the Sun. The breadth of Saturn's rings is 700 times their thickness, but since there are distances between them, let us subtract a good round sum, so far as the nebula is concerned, and say that the breadth of its rings was only 100 times its thickness. If we then multiply 3,636,842 by 100 we get 363,-648,200, which indicates in miles the breadth of the ring. If we further multiply its breadth by its thickness and the product of this by 17 billion miles, which is the length of the Neptunean orbit, we get its contents, which amounts to more than 22 septillion cubic miles. Thus we find, that this ring would contain matter enough to form 50,000 solar system like ours. And still we have used very conservative figures and assumed its matter to be no denser than air.

It is evident, therefore, that the planet Neptune cannot have been formed out of such a ring or out of a ring of sucn a nebula. This, then, indicates another origin of Neptune, than that proposed by the nebular hypothesis, and another origin of the other planets also.

Thus it is plain, at this point too, that planets are not made of rings. Furthermore, we understand, that the rings of Saturn serve some other purpose than to make moons, and that these have an origin independent of that of the planets.

This must be said in favor of Laplace, however, that if the solar system had been explored to the same extent in his time as it is now, his theory would very likely never have appeared in the form in which it is here presented. But less can be said in favor of the modern advocates of the theory, especially after the discovery of Neptune one thousand million miles farther out than Uranus. John Fiske has gone even so far, that before the moons of Mars were discovered, he tried to explain, in the light of the nebular theory, why Mars had no moons. After the discovery of the moons of Mars, G. H. Darwin has tried to

demonstrate, by the strength of the same theory, why Mars has *two* moons.

There are many other things that could be brought against the nebular theory, for instance, the question about the origin of the comets, which it cannot answer; but since we have already shown its untenableness, we cannot gain anything by further argumentation against it. We may add, however, that what we have said so far, will appear much clearer and be more easily understood as we go on with the explanation of the real causes which have produced the natural phenomena, which, as we have shown, hitherto have been so totally misunderstood.

(To be Continued.)

THE BARABOO IRON ORE.

By N. H. WINCHELL, Minneapolis.

One of the notable publications relating to the iron ores of the Northwest is that of Dr. Weidman, of the Wisconsin survey, lately issued by the State of Wisconsin.* According to the report this iron ore occurs in the "pre-Cambrian," in which are included rhyolyte, granite and dioryte, occurring in isolated outcrops, these all being considered parts of the Archean. The rhyolyte is a very hard, pinkish red rock which is usually unweathered and breaks under a stroke of the hammer with sharp conchoidal fractures. It contains numerous crystals of pinkish feldspar and translucent quartz, which are imbedded in a very fine matrix or ground mass. It fractures sometimes naturally in all directions, so that it appears about the outcrops in the form of multitudes of small angular pieces. It is frequently veined by quartz. It is described by Dr. Weidman as having been a surface or volcanic igneous rock, its groundmass representing the glassy part of the igneous flow, cooled too quickly to become entirely crystallized. It is discovered microscopically that the crystals of quartz and of feldspar contained in this rhyolyte have sometimes been broken, and that between the parts thus formed the viscous magma has flowed. In other cases these crystals are bent. These distortions are assigned to a date prior to the solidifica-

* "The Baraboo Iron Bearing District of Wisconsin," SAMUEL WEIDMAN. *Wisconsin Geological and Natural History Survey*, Bulletin No. 13, Madison, 1904.

tion of the rock, and are features well known in the red quartz porphyries of the Keweenawan. The rock also shows fluxion, poikilitic and spherulitic structures. Certain gray sericitic schists that occur between this rhyolyte and the overlying quartzyte or conglomerate are supposed to be a part of the rhyolyte rendered schistose and sericitic by dynamic pressure and crushing, although the zone occupied by these schists is sometimes 150 or 200 feet wide, and "may in places contain some sedimentary rock." In the same manner an arkose-like schistose zone lies between the granite and the quartzyte that overlies, and is thought to be due to alteration of the granite by dynamic pressure. A question might arise, whether, in the light of the author's descriptions, the dioryte should be considred a different rock from the granite. These igneous rocks are considered the basement floor on which, with a structural non-conformity, the quartzyte and its basal conglomerate were deposited.

The Baraboo series comprises three parts: (1) the Baraboo quartzyte formation, consisting mainly of quartzyte but containing also a small amount of conglomerate at its base, (2) the Seeley slate formation, consisting of a quite uniform gray clay slate, and (3) the Freedom formation, consisting of two members, a lower, of iron ore, ferruginous slates, ferruginous dolomyte and ferruginous chert, and an upper, of dolomyte.

The first mentioned of these (Baraboo quartzyte) is well known, having been described several times by different geologists. It is unquestionably a very widespread formation, extending into northern Wisconsin, into Minnesota and to northwestern Iowa. It has been styled Barron County quartzyte, New Ulm quartzyte and Sioux quartzyte. It is in several places accompanied by red slate, hardened and semi-metamorphosed, making the well-known catlinyte in Pipestone county, Minnesota. It was first named by Dr. C. A. White, *Sioux quartzyte,* from its outcrops in northwestern Iowa. The catlinyte beds of Pipestone county in Minnesota and of Barron county, Wis., are perhaps represented at Baraboo by the more clayey and schistose beds enclosed in the quartzyte, now converted to a schist, as described by Dr. Weidman, by shear and differential movement incident to the uplifting of the quartzyte ranges. Near Ablemain's such uplifting so fractured

the quartzyte that on reconcentration by white quartz it presents the composition and structure of Reibungs breccia. In general this quartzyte is cemented by "interstitial" quartz, and small amounts of iron oxide, chlorite and sericite.

The conglomerate underlying the quartzyte is essentially composed, even where it lies on or near the granite, of rolled and angular pieces of the rhyolyte, i. e., it is a *quartz porphyry conglomerate* indistinguishable from the red conglomerates of the Keweenawan. It contains, however, a little black slate, some pebbles of greenstone and some of ferruginous chert rocks, in that respect resembling the conglomerate underlying the New Ulm quartzyte of Minnesota.

The so-called "intra-formational" conglomerate beds situated on or in the qurtzyte, should not perhaps receive that designation since after careful examination microscopically by Dr. Weidman they do not contain any pebbles of the underlying Baraboo quartzyte, but consist of "pebbles of chert containing considerable iron oxide and also a few pebbles of slate, but mainly of pebbles of vein quartz or of quartzyte like the Rib Hill quartzyte in north central Wisconsin." Such coarse fragmental material, entirely foreign to the quartzyte underlying and overlying, indicates the sudden occurrence of powerful transporting currents in the ocean which ordinarily deposited the fine-grained quartzyte. What may have been the cause of such powerful currents the author does not enquire, but it has a suggestive relation to the Keweenawan. What may have been the source of the "ferruginous chert," which we suppose is the same rock as that term expresses in other publications by the Wisconsin geologists, the author does not inquire, but it has an important bearing on the age of the quartzyte in which these pebbles exist.

Dr. Weidman has made a very important contribution to geology in establishing the structural relations of the quartzyte to the rhyolyte and the granite of the district. Very different conceptions of these relations had been published by different geologists of the Wisconsin survey. Dr. Weidman shows by a mass of detailed field observations that the quartzyte is younger instead of older than the quartz porphyry, that the structure of the region, instead of being monoclinal as thought by Irving and by Chamberlin, or anticlinal as conceiv-

ed by Salisbury and Atwood, is synclinal and the thickness of the formation less than half as much as calculated by the other geologists. The writer has a personal satisfaction in this result, since, in several general discussions of the geology of the Northwest he has compared the Baraboo region with the geology of Minnesota and has insisted that the Baraboo quartzyte is later in date than the Keweenawan quartz porphyries and later than the Animikie iron ore, on the ground that its Minnesota representatives are found unquestionably to occupy such a stratigraphic position. From several calculations the author derives an average result for the thickness of the Baraboo quartzyte, viz: between 4000 and 5000 feet, without allowing for any faulting. This result is probably too high, since it is not likely that there is an absence of such movements, or even of profound faulting, such as would cause an elongation of the surface exposure and hence an elongation of the hypotenuse of the triangle of dip. Probably these figures, reduced fifty per cent, would more nearly express the actual thickness.

Above the quartzyte is the Seeley slate, which is known only by underground exploration, having no surface outcrops. By mining operations and drilling it is traceable along the north side of the south quartzyte range a distance of six or seven miles. It is gray, cleaved somewhat like roofing slates, and so soft that it can generally be whittled with a knife. It is a sedimentary rock and its petrographic description and composition indicate that it is not free from volcanic elements. Indeed, its reference largely, or wholly, to the agency of igneous action, a sedimented volcanic ash containing more or less of other detritus, would be in keeping with the characters given to it by Dr. Weidman. In that case it is a rotted igneous ash modified by sedimentary elements. The fact that it shows commonly a well developed diagonal slaty cleavage implies differential pressure and shearing in the formation, such as would materially affect any calculation of its thickness unless it be allowed for, as above suggested for the quartzyte. The thickness of this soft shaly slate is placed by the author at 500 to 1000 feet, but it may be considerably more, as only the roughest estimates can be made. In Minnesota this slate, or what lies above the great quartzyte, is well known, having

been penetrated by a large number of deep wells, and having developed a thickness of nearly 2000 feet. It varies from gray (or greenish) to red, but its products under the action of a common drill always appear red. The earliest published account of this formation is to be found in the second annual report of the Minnesota survey, where it was described in the record of the Belle Plaine salt well, where it was penetrated about 500 feet. Subsequently it has been encountered in every deep well sunk in this part of the state. It is spread out horizontally over a large area in Minnesota. It is somewhat interstratified with quartzyte downwardly and with sandstone upwardly, fading out in both directions by changing to such rocks. It extends to Sioux Falls in S. Dakota where it colors the till locally, being charged with iron oxide. It is mentioned in all the Minnesota reports that relate to this stratigraphic horizon.

The Freedom formation, which is the iron-bearing member, "consists of a variety of rock, including slate, chert, dolomyte, and iron ore and all gradational phases between those kinds of rock." The dolomyte is said to be the most abundant of these varieties, and alone to compose the upper part of the Freedom formation. Its thickness is 500 feet, but was probably at first much more than 500 feet. In Minnesota this horizon has not been distinguished, but the whole shaly mass above the quartzyte has been considered essentially as one formation. So far as known no dolomyte has been discovered, but in only three instances have drill cores, or drillings been examined with care, and those pertained to the upper portions of the member, viz: the Belle Plaine Salt well, the Mankato deep well and the Glencoe well. The deep well at the Lakewood Cemetary, at Minneapolis,* was sunk into the Seeley gray slate about 33 feet. The East Minneapolis deep well and the Mankato deep well were limited to the upper portion of the Freedom formation. The Glencoe deep well passed through 315 feet of red quartzyte below the Hinckley sandstone and the Fond du Lac red sandstone, and again entered a red shale, in which the well stopped after penetrating it 230 feet.† This quartzyte is supposed to be the representative of the New Ulm

* *Final Report of the Minnesota Geological Survey*, vol. ii, pp. 182-186.

† *Atlas Volume of the Final Report, Minnesota Survey*, plate xxxvii, McLeod county.

quartzyte which appears on the Minnesota river a few miles south of Glencoe, which has been without exception parallelized with the Baraboo quartzyte, but it may be a quartzyte stratum separated from the main quartzyte by a stratum of red shale. In several cases such interstratified shale beds have been observed. The pipestone, or catlinyte, layer at Pipestone, Minnesota, is a familiar instance. Indeed, the New Ulm quartzyte itself is rather shaly than quartzitic in its lower layers and the red color is to a large extent, a superficial feature. The outcrop of the underlying conglomerate is so far removed from the quartzyte outcrop that intervening room exists for a great thickness of shale or shaly quartzyte.

The iron ore of the formation (hematite and siderite) is somewhat different from all the iron ore deposits of the lake Superior region in its mineralogical associations. The chief of these differences consists in the presence of a large amount of dolomite. This carbonate develops into important strata which, being crystalline, are denominated marble. Much of it is affected by the presence of iron, and sometimes by manganese. The general term ferrodolomite is usually applicable. The iron ore grades into this rock, and also into ferruginous chert, and into ferruginous slate by insensible changes, resembling in all respects the gradations seen in sedimentary rock from one to another. The workable ore occurs at different horizons, the deposits being conformable with the strata, varying from thirty feet thick to two hundred feet, in the form of more or less elongated lenses. The author remarks that this ore deposit has more similarity to the ores of post-Cambrian, such as the Clinton ore, than any of the known ores of the lake Superior region. Still, notwithstanding these differences, there are greater bonds of alliance with the other ores of the lake Superior region by reason of which this ore can be classed, with strict propriety, with the well known ores of the Northwest. The chief difference, above noted, is one furthermore that does not always obtain, for in the eastern end of the Mesabi iron range the iron horizon is accompanied by a deposit of ferro-dolomite or dolomitic siderite which constitutes a noteworthy stratum in the base of the Animikie,* and its origin and significance have been discussed by the writer.

* *Final Report of the Minnesota Geological Survey*, pp. 312, 638, 997.

In Minnesota this ferrodolomyte as a rock mass is more nearly a dolomitic sideryte.

The author fully considers the subject of underground water and its agency as a possible producer of this ore, as has been urged for the other ores of the lake Superior region. By the steps of such investigation such origination is excluded, because, (1) the minerals in solution in the underground waters are not noticeably different from those in solution in surface waters; (2) the minerals deposited in the overlying sandstone are not iron but silica and lime, the latter in small amount; (3) river waters often hold in solution iron in greater quantity than is now contained in the underground water of the Baraboo district; (4) the iron in underground waters is held in solution until the waters are exposed to the oxidizing action of the atmosphere at the mouths of springs; or by the action of iron bacteria; (5) the iron of the formation was deposited prior to the formation of the numerous quartz veins that penetrate the beds, i. e. prior to the upheaval and tilting that fractured the strata; (6) these veins are quartz, with very small amounts of lime and of iron sulphide, and they must have been formed by underground waters; (7) the relations of the ore to the containing rocks in everyway indicate that the ore originated cotemporary with the deposition of the rocks as sediments.

As to the origin of the ore the author states that he believes that it was originally a deposit of ferric hydrate, or limonite, formed in comparatively stagnant and shallow water, under conditions similar to those existing when bog or lake ores are being formed to-day, and that such ore has been altered by heat and pressure to hematite. He also believes that organisms played an important part in the formation of the strata of hematite, as well as of the strata of dolomyte and chert—that too, although he considers the associated rocks as a part of the Archean (Lower Keewatin). It is the first suggestion of evidence of organic life in the Archean, excepting only the Eozoon canadense whose organic nature is quite generally discredited at the present time, and whose statigraphic position may be considerably higher than the Lower Keewatin, and perhaps of the Lower Cambrian. The author believes that the shallow waters were subject to alternating changes

of depth and physical surroundings, and that the waters held considerable iron in solution derived from iron-bearing rocks of adjacent land areas. He states in detail the evidence supporting this hypothesis. But few geologists will question his interpretation of the evidence. The idea that the iron ores of the lake Superior region have resulted from the metasomatic alteration of a "cherty carbonate" on a grand scale, suggested by Irving, lingers in certain quarters to this day. Indeed it is the fundamental conception held by the United States geologists who have labored in the Lake Superior region, although, from the force of the evidence, more lately the presence of a "green silicate" in the original rock has been recognized as an important source of much of the ore. That the iron now present in the rocks had its origin in sedimentation, and dates from the formation of the rocks themselves, and has simply suffered transformation of its chemical composition, resulting in different iron minerals, is becoming more and more widely proven. This process is one of metamorphism, due to the same forces that have converted many rocks from a state of simple sedimentary strata into schists and gneisses. The elements were all (or essentially all) present at first. They have taken on new forms of chemical combination, and have been locally concentrated. The writer is entirely in accord with Dr. Weidman in this explanation. The author would have found this theory applied to the iron ores of Minnesota by the writer thirteen years ago (though with scant recognition of the agency of decaying organic matter) had he consulted Bulletin No. 6 of the Minnesota Geological Survey, pp. 103-111.* If there be any difference between the author's and the writer's views it is in relation to the environment of the sedimentary action. The author seems to require quiet, shallow water, subject to slight, alternating fluctuations of level, but a steadily sinking sea bottom, the iron solution in the water derived from adjacent land areas. Rather the writer maintained that the sea was hot, incapable of supporting organic beings, and that the ferric hydrate was a chemical sediment. With later observation it has become apparent that hot waters shaded off into tepid waters, and that chemical sediment was widely

* This view was first published in the AMERICAN GEOLOGIST, vol. IV, pp. 291-300, 1889.

mingled with detrital sediment, thus warranting the assumption of the action of organic agencies and the general cotemporary prevalence of ordinary detrital sedimentation at other points. The writer believes that all the facts that have been brought to light bearing on the origin of the lake Superior ores warrant the conclusion that these ores in their first condition resulted from the chemical action of oceanic waters on volcanic rocks, and that they were cotemporary, from the oldest to the youngest, with epochs of unwonted volcanic activity. The discussion of this view as to the older iron ranges has been presented, in an incomplete manner, in volume five of the final report of the Minnesota survey, and earlier in Bulletin No. 6 of the same survey.

Referring to that report for reasons for this belief, it may be well to consider reasons for assuming that the Baraboo ore should be assigned to a similar volcanic epoch.

1. In the final discussion of the Keweenawan igneous rocks the writer divided them into two great divisions, to which he gave the names Cabotian and Manitou, the former being the older. The Cabotian contains the gabbro and anorthosytes, the so-called red-rocks, i. e., the red quartz porphyries, the red granites and the felsytes, and numerous red-rock surface lavas. In the Cabotian are also many important basic lava flow rocks now much rotted. In the Manitou are only basic lavas and alternating sandstones and shales, with rare conglomerates, the lavas gradually fading out and giving place to a formation of great thickness, of shale and shaly sandstone.

2. In the course of about 15 years of study and field examination in the Archean and Taconic rocks of the lake Superior region the writer has found no red quartz porphyry below the base of the Animikie. It seems to be confined to the Keweenawan. It is true that in Wisconsin are several isolated knobs of quartz porphyry that have been assigned to the Archean, but there is no evidence whatever that they are not cotemporary with similar knobs further north that are well known to belong to the Keewcenawan.

3. The writer has shown conclusively that the conglomcrate lying at the base of the New Ulm quartzyte is of later date than the Animikie and hence later than the Mesabi ore. He accepts the unanimous assumption that the Baraboo quartzyte.

the Sioux quartzyte and the Barron County quartzyte are all on practically the same stratigraphic horizon, and the same horizon as the New Ulm quartzyte.

4. Hence the Baraboo iron ore is later than the Animikie, and the Baraboo conglomerate and quartzyte are the sedimentary equivalents of the Puckwunge conglomerate and quartzyte.

5. Therefore the Baraboo iron ore being later than the red rhyolyte is in the proper stratigraphic place to be cotemporary with the Manitou igneous epoch of the Keweenawan, and was accumulated under conditions that were identical with those shown by the writer to have prevailed when the ores of the Vermilion range and of the Mesabi range were deposited.

The writer has described the Puckwunge conglomerate as the fragmental base of the Manitou epoch of the Keweenawan, and non-conformable on the Cabotian, and also non-conformable (owing to subsidence of the lake Superior region) on several older formations. The subsidence which was later and is well known as the cause of such non-conformity of the Upper Cambrian on older formations (even on Archean) seems to have begun far back in the Keweenawan and to have produced a progressive non-conformity of the Manitou rocks (or their associated fragmentals) on the still older rocks.

The author of this volume has made an important contribution to the question of the origin of iron ore, in showing that the Baraboo iron was not the product of metasomatic alteration of other rocks by the agency of underground water, and hence, owing to the common links that bind it with the ore of other iron ranges, that probably none of the lake Superior ores were due to any important degree, to the action of underground waters. Still such waters have played doubtless an important part in changing the ore from one mineral condition to another, and perhaps to some extent in transporting it and concentrating it in certain strata where heat and pressure have co-operated to produce crystalline hematite. The author is to be congratulated for the thorough and independent manner of this investigation.

It would have been a fortunate thing if he had been equally independent and thorough in assigning the Baraboo ore to its stratigraphic place. He has tentatively put it somewhere in

the Archean, amongst the rocks that hold the ores near Marquette, but it is plain that, if the foregoing exhibit of the stratigraphic relations of the Baraboo rocks be correct, the Baraboo ore is chronologically about equivalent to the Manitou epoch of the Keweenawan.

In conclusion attention may be called to a former statement by the writer of facts that indicate that the quartzyte at the falls of Pokegama on the upper Mississippi is more recent than some parts of the Keweenawan, and that hence it does not pass below the Mesabi iron ore, but may be the equivalent of the Puckwunge conglomerate and quartzyte. There has never been any demonstration of the age of this quartzyte. It is known to lie on the granite of the Giant's range but the age of the Giant's range of granite is, according to H. V. Winchell and Prof. C. K. Leith, later than the Animikie. The age of the Giant's range granite has pretty generally been accepted as pre-Animikie, and hence Archean. Of course if it be later than the Animikie it will parallelize with the granite associated with the gabbro, and the age of the ores of the Mesabi range, in its western part at least, would come into question.

At this point the facts referred to above are apropos. They are published in volume 5, of the Minnesota final report, p. 692. In making a final microscopical examination of some of the slides it was found that the conglomeratic portions of the Pokegama quartzyte which passes below the ore at Prairie River falls hold a few pebbles and fragments of rock that can be derived only from some parts of the Keweenawan, and that hence some part of the iron ore of the Mesabi range, as described and mapped, is later than the Animikie and later than some part of the Keweenawan. It is a remarkable fact also that the rock that overlies the ore and the quartzyte, in the vicinity of the Diamond mine, east of Pokegama falls, is a red, soft, unctuous shale undistinguishable from the shales of the Keweenawan that are well known.

It hence appears probable that the stratigraphic relations of some of the iron ore deposits of the lake Superior region are not well understood and need to be re-considered. Taking together the facts about Pokegama falls and the new developments at Baraboo it seems to be pretty certain that there is an ore horizon in the Keweenawan about on the chronological

horizon of the igneous rocks of the Manitou epoch. It is possible that the next lower iron ore is similarly related to the Cabotian, the oldest igneous rocks of the Keweenawan. It would be no abnormal fact that the highly ferruginous shales of the Keweenawan should be found to afford in some places so concentrated a condition of their contained hematite as to become economically a valuable iron.

THE CRETACEOUS EXPOSURE NEAR CLIFFWOOD, N. J.

By Edward W. Berry, Passaic, N. J.

PLATE XV.

In the January number of the AMERICAN GEOLOGIST there appeared an article criticising certain views ascribed to the writer as to the proper correlation of the Cretaceous clays which outcrop on Raritan bay in the vicinity of Cliffwood, N. J. The Article in question is written in a tone that should not be permitted in a scientific discussion, particularly as the paper criticised was intended as a contribution to paleobotany, the geological discussion being merely introductory and advancing no new ideas or correlations; on the contrary it contained simply a brief resume of the opinions of the several geologists who had studied this exposure and whose mature opinions had been before the public for a number of years. Should subsequent facts warrant, which it seems to me they fall far short of doing at present, the reference of these clays to the Raritan formation I would most readily accept this conclusion, although the evidence of the contained flora, largely misunderstood and misinterpreted by Knapp, does not warrant such a conclusion.

Professor Wm. B. Clark who named the formation and mapped it for the United States Geological Survey, and whose views I followed in a general way in my article above referred to writes me in part as follows in response to a letter asking for his opinion:

"There is no question as to the [illegible] of the Matawan-Raritan contact from the Potomac valley [illegible]. It is one of the most marked stratigraphic features in the Maryland-New Jersey Cretaceous belt. As we approach the Raritan river at Cliffwood bluff coming

north, however, this sharp distinction between the Matawan above and the Raritan below is less pronounced and I have always been a good deal puzzled by the Cliffwood section as there seemed to be a lens of different materials lying between the typical Raritan below and to the westward and the typical Matawan above and to the eastward. This lens it is true is more sandy in places than the typical basal beds of the Matawan, but it contains, on the other hand, patches of glauconitic materials which I have never observed in the Raritan. Furthermore, while the contact of the Cliffwood lens with the more characteristic Matawan above is not sharp and distinct* there is a marked difference between these materials and the typical Raritan below.

"Considering all the evidence at hand it seemed to me that this lens of dark clays and laminated sands, at times glauconitic, ought rather to be included with the Matawan above than with the Raritan below. I therefore incorporated it tentatively with the Crosswicks clays, or basal Matawan, to which I am still inclined to believe it belongs since reading your article on the paleobotany. It is not surprising that a large proportion of Raritan plant species still continue on into the lower Matawan as the same takes place in the formations below the Raritan in Maryland and Virginia. . . . It would not be surprising that with the advent of Matawan deposition certain small included areas of deposition might exist at the time of the encroachment of the sea which would be contemporaneous with the more distinctly marine facies elsewhere. The production of glauconite is an extremely significant fact and is characteristic of the opening of Matawan deposition throughout the entire region to the southwestward as far as the Potomac valley where the Matawan finally disappears by the transgression of the Eocene. It is irregularly glauconitic and often sandy south of the Delaware although no fossil leaves have been found as yet.

"The point at issue does not strike me as of any great importance and if further investigation should show conclusively that these beds at Cliffwood should be included in the Raritan I should have no hesitancy in accepting the results. I think the data thus far furnished, however, point more strongly to the Matawan than to the Raritan, but here is a chance for an honest difference of opinion."

Personally I have not studied the exposure to the southwestward, nor do I feel competent to pass judgment on the stratigraphic details, and I desire in the following notes to set forth the evidence that is furnished by the plant remains.

The typical Raritan flora contains numerous old types, representatives of plants from the arctic Urgonian (Kome beds), such as *Gleichenia micromera* Heer; representatives of *Cycadinocarpus*, which is almost exclusively a Triassic and Jurassic genus; representatives of *Czekanowskia* which is a

* This statement should be qualified considerably.

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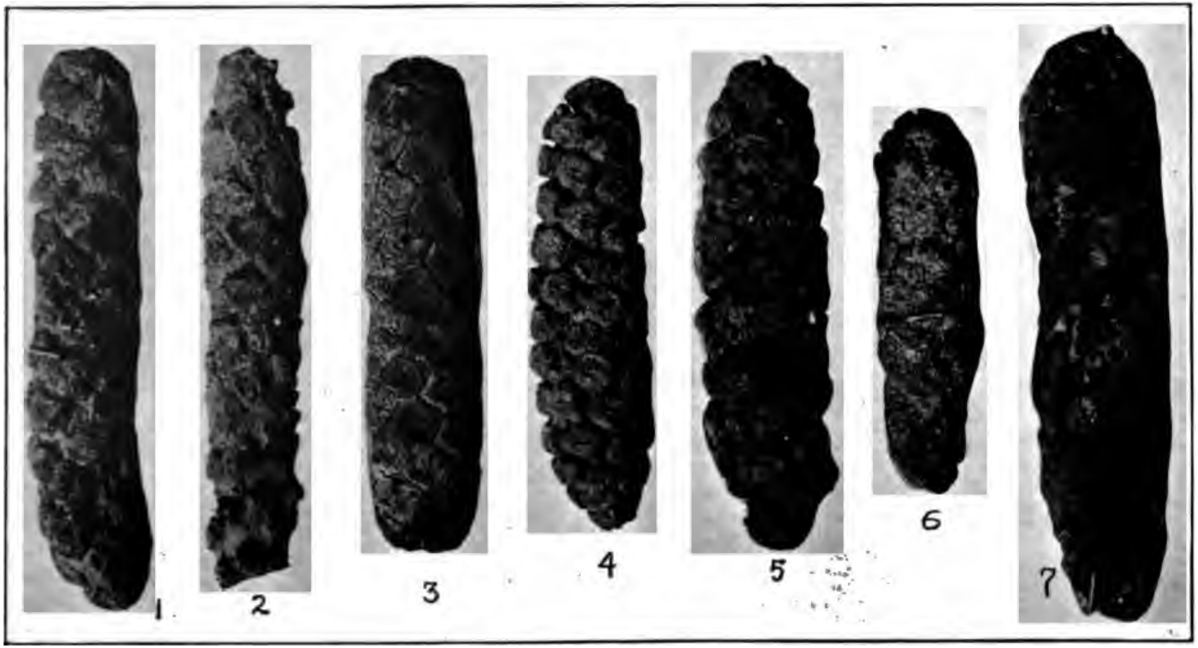

CONES OF SEQUOIA GRACILLIMA (LESQ.) NEWB.

Jurassic genus; *Brachyphyllum* which is chiefly a Jurassic genus, although it occurs also in the Triassic; representatives of *Baiera* and the allied genus *Sclerophyllina* which are Triassis, Jurassis, and Necomian.

Podozamites angustifolius (Eichw.) Schimp, which is recorded by Heer from the Jurassic of Siberia and Spitzbergen reappears in the Raritan.

In addition to these ancient types, the Raritan abounds in species, often of common occurrence, which have not been detected at Cliffwood. Such examples are *Sequoia heterophylla* Vel., *Widdringtonia* (two species), *Celastrophyllum* (nine species), *Myrica* (seven species), and species in thirty-three other genera which are unrepresented at Cliffwood.

Knapp erroneously says that 64 per cent. of the Cliffwood species are identical with the Raritan flora at Woodbridge. As a matter of fact, in the paper he has criticised only 29 per cent. of the plants were represented in the whole Raritan formation.

Further contributions have increased the percentage of Raritan species found at Cliffwood to 37 per cent. Against this may be placed 44 per cent of forms common to the Cenomanian of this country and Europe, the detailed distribution of which may be readily seen in the table of species accompanying this article.

By far the most common fossils at Cliffwood are *Cunninghamites squamosus* Heer, *Dammara cliffwoodensis* Hollick, *Sequoia reichenbachi* (Gein.) Heer, and *Sequoia gracillima* (Lesq.) Newb. Of these, *Sequoia reichenbachi* ranges from the Neocomian through the Danian, and is a very widespread form. The balance are peculiar to Cliffwood and higher horizons, thus *Cunninghamites squamosus* occurs elsewhere only in the Senonian of Saxony.

The imperfectly petrified cones of *Sequoia gracillima* are excessively common at Cliffwood, the writer having collected hundreds of specimens not only from the wash on the beach but also in place in the clays. They are sometimes very perfectly preserved and are very characteristic objects (see plate), yet to my knowledge they have never been detected in the Raritan formation, although the latter has been opened up everywhere for the clay and been extensively collected over.

MATAWAN	Potomac	Spitzbergen	Trinity	Kome	Black Hills	Kootanie	Austrian Silesia	Switzerland	Tuscaloosa, Ala.	Belvidere, Kan.	Staten Is.	Long Is.
	NEOCOMIAN.			URGONIAN					ALBIAN			
Acer paucidentatum												
Andromeda parlatorii									x		x	x
Aralia brittoniana												
Aralia mattewanensis												
Aralia groenlandica												
Aralia palmata												
Aralia ravniana												
Aralia towneri												
Araucarites ovatus												
Arisaema cretaceum												
" (?) mattewanense												
Banksia pusilla												
Carpolithus cliffwoodensis												
" drupaeformis												
" judglandiformis												
" ostryaformis												
Celastrophyllum elegans												
" newberryanum												
Chondrites flexuosus												
Confervites dubius												
Cunninghamites elegans							x					
" squamosus												
Dammara cliffwoodensis												
Dewalquea groenlandica									x		x	
Eucalyptus dubia												
" geinitzi										x	x	x
Ficus atavina												x
" reticulata												
" woodsoni									x		x	
Frenelopsis hoheneggeri (?)			x	x			x					
Geinitzia formosa												
Gleichenia saundersii												
" zippei		x		x	x							
Gymnospermous cone												
" stem												
Laurus hollae											x	
" hollickii												
" plutonia												x
" proteaefolia												
Laurophyllum angustifolium												
Liriodendropsis angustifolia									x			x
Magnolia capellinii												
" obtusata												
" speciosa									x			x
" tenuifolia												
" woodbridgensis												
Microzamia (?) sp.												
Moriconia cyclotoxon											x	
Myrica cliffwoodensis												
" [illegible]												

…LT		CENOMANIAN						TURONIAN		SENONIAN						DANIAN		
Block Is.	Raritan	Bohemia	Saxony	Moravia	Greenland	Mill Creek	Dakota	Saxony	Peace and Pine Rivers	Westphalia	Rhenish, Prussia	Saxony	France	Bohemia	Greenland	Vancouver	Belly River	Montana
	x				x		x											
	x				x		x											
	x																	
					x													
							x											
							x											
		x																
	x																	
	x																	
	?	x		x						x					x			?
												x						
	x				x										x			
	x	x		x			x											
		?			x										x			
							x											
	x																	
	x																	
	x			x								x						x
	x	x			x							x		x	x			
					x		x											
x	x	x			x		x								x			
							x											
	x				?													
	x																	
	?	x			x		x									x		
					x		x											
		x																
							x		x									
x	x																	
x	x										x				x			

MATAWAN*	NEOCOMIAN			URGONIAN				ALBIAN				
	Potomac	Spitzbergen	Trinity	Kome	Black Hills	Kootanie	Austrian, Silesia	Switzerland	Tuscaloosa, Ala.	Belvidere, Kan.	Staten Is.	Long Is.
Myrsine crassa												
Nelumbo primaeva												
Palinurus integrifolius												x
Phragmites (?) cliffwoodensis												
Pinus delicatulus												
" mattewanensis												
Pityoxylon hollicki												
Podozamites marginatus												
Populites tenuifolius												
Proteoides daphnogenoides									x	x	x	x
Protophyllocladus subintegrifolius											x	
Quercus hollickii												
" holmesii												
" morrisoniana												
" (?) novae-caesareae												
" eoprinoides												
" sp.												
Rhamnus inaequilateris												
" nova-caesareae												
Salix mattewanensis												
" meekii												
" proteaefolia flexuosa												x
Sassafras acutilobum												x
" progenitor												x
Sapindus apiculatus												
" morrisoni											x	x
Sequoia gracillima†									x	x		
" reichenbachi	x	x		x		x	x	x	x		x	
Sterculia cliffwoodensis												
" mucronata												
" snowii bilobatum												
" sp.												
Strobilites inquirendus												
Tricalycites papyraceus									x		x	x
Viburnum hollickii												
" mattewanense												

This is a very significant fact, an abundant and well preserved type such as this far outweighing merely negative evidence or percentages of species common to two formations.

In considering the members of the genus *Aralia* which are found at Cliffwood we find that the one species otherwise confined to the Raritan (*Aralia palmata*) is not exactly identical

*Carpites minutulus Lesq. recorded from the Denver group at Golden, Col., has recently been detected at Cliffwood, N. J.

† Localities under this species represent foliage doubtfully related to the cones of the Matawan.

AULT)			CENOMANIAN						TURONIAN		SENONIAN						DANIAN		
Vineyard	Block Is.	Raritan	Bohemia	Saxony	Moravia	Greenland	Mill Creek	Dakota	Saxony	Peace and Pine Rivers	Westphalia	Rhenish, Prussia	Saxony	France	Bohemia	Greenland	Vancouver	Belly River	Montana
								x											
		x				x													
		x					x	x											
x	x	x				x		x											
								?									x		
								x											
								x											
								x											
	x							x											
x		x	x					x											
x		x																	
			x																
x						x		x								x			
								x		x									
		x	x	x	x	x		x	x		x	x	x	?				x	x
								x											
x	x	x																	

but shows a progressive development of lobes, and is more abundant in the later formation. Of the other species of this genus two are very large-leaved Cenomanian forms (*rawniana* and *towneri*). In the genus Quercus we find at Cliffwood a representative of a Laramie species, another common to the Dakota group, a third closely related to the living *Quercus prinoides* Willd.

None of the six Matawan species of this genus are found in the Raritan, in fact the genus is only sparingly represented in that formation.

The two species *Rhamnus* and the four species of *Sterculia* all point to the relation of the Cliffwood flora to those of higher horizons.

In the genus *Nelumbo* we have a small leaved species at Cliffwood which Hollick considers as probably identical with his *Nelumbo laramiensis* from the Laramie formation.

Further than this, if we were to eliminate from our discussion Raritan forms of rare occurrence in the Matawan, and evidently waning type, such as *Tricalycites papyraceous* and *Protophyllocladus subintegrifolius*, each represented by but a single specimen, the differences between the two floras would be greatly emphasized.

The Cliffwood clays also contain many representatives of distinctly later types—thus *Viburnum* has two positively identified species, the genus being unrepresented in earlier strata.* Similar evidence is furnished by representatives of the genera *Arisaema, Ficus, Banksia, Laurus, Magnolia, Myrsine, Sapindus*, etc.

The botanical evidence is capable of much fuller amplification than I have thought necessary to give it in the foregoing notes, and I have no hesitation in saying that the Cliffwood flora is not only perfectly distinct from the Raritan flora, but that the old types in the latter are replaced by more modern types in the former, and clearly point to the greater age of the Raritan flora. If subsequent facts should prove the intimate stratigraphic connection of these beds with the Raritan the flora would nevertheless prove that this horizon (at Cliffwood) is a biological, if not a stratigraphic unit.

* A species from the Raritan referred to the genus by Newberry is obviously not a *Viburnum*.

REVIEW OF RECENT GEOLOGICAL LITERATURE.

The occurrence and exploitation of petroleum and natural gas in Ohio. JOHN ADAMS BOWNOCKER. Fourth series, Bulletin No. 1, of the Geological Survey of Ohio, EDWARD ORTON, JR. State Geologist, Columbus, O. December, 1903, pp. 325, xxi with maps, 6 plates.

Excepting a brief historical sketch of the organization and work of the Geological survey of Ohio by Prof. Orton, this volume is devoted to oil and gas by Prof. Bownocker. The chapters are; The oil and gas producing rocks of Ohio; The Trenton limestone as a source of oil and gas; The Clinton formation as a source of oil and gas; The Carboniferous rocks as a source of oil and gas; The origin of oil and gas, and geological conditions under which they are found

Above the Trenton limestone, the lowest gas producing rock of Ohio, commercial quantities of oil and gas have been found in a large number of formations reaching as high as the Monongahela formation, the Upper Productive Coal Measures of the Carboniferous. The author discusses fifteen. He gives in detail the history of exploitation at the various fields, entering into the methods of various municipalities to secure free gas for manufacturing establishments, and cheap gas for the citizen. Toledo has had a very unfortunate and costly experience. After an expenditure of two millions of dollars to establish a municipal gas plant it has now only an annual income of $9,500, derived from the rent paid by a private company for the use of the city's distributing gas lines. The history of Findlay reads like a romance--discovery, excitement, speculation, extravagant use and waste, boom, wane, collapse, and a scampering of the speculators to the new fields of Indiana. Oil when it accompanied gas, was at that time regarded a nuisance. This was in the eighties. Gradually, as the prevalence of oil in the same regions and in the same rocks, became an aggressive economic fact, efforts were turned to its utilization. At the date of 1901 the Trenton limestone produced in Ohio the enormous supply of 16,176,292 barrels. The greatest supply from this source in Ohio was in 1896, reaching 20,575,138 barrels. The total oil supply in the United States for those years was respectively 69,380,194 barrels and 60,960,361 barrels. Oil is therefore now by far the greater of these sources of wealth, but according to symptoms that are well known it also is fast going over the same road to exhaustion. Wells are being abandoned, and the great flowers are much reduced, salt water threatening to be their doom. The counties of the state have all been tested by drilled wells, some of them having scores and even thousands, so that the resources of the state in this direction are practically known. The reservoirs, or "pools" of oil as well as of gas have probably all been discovered. This report serves to put on record and to preserve the history of what has been probably the most important and exciting run of

economic geological exploitation ever witnessed. It has not involved so large sums of money as some of the mining enterprises of the Rocky mountain region, but it has been spread over a greater area, and has affected the happiness of a greater number of people.

The hight of the industry has gradually moved eastward and southeastward, at the same time being centered in later formations. The Clinton formation supplies the gas at present consumed at Columbus and surrounding country, taken from the wells near Lancaster and Homer about forty miles east of Columbus. In Washington county in the eastern part of the state, and in other counties lying on the Ohio river both gas and oil are obtained in large quantities from the upper portions of the Carboniferous formation.

In reading the pages of this report the geologist is painfully struck by the use made of the following stratigraphical terms:

First Cow Run sand.
Second Cow Run sand.
Big Injun sand.
Squaw sand.
Hurry-up sand.
Goose Run sand.

Such trivial names, applied by the operators and current in the localities where these sands are known, might be replaced by terms more in keeping with the science—at least they might be restricted as local and vulgar terms not appropriate for the dignity of geological nomenclature.

As to the origin of gas and petroleum the author states the arguments for the chemical, or inorganic theory as well as those of the organic or geological theory. While admitting that no conclusion has been reached by scientists, and that therefore no positive statement can be made, it is apparent that the author inclines to the organic origin of these substances. His summary of the investigations of the chemical processes is interesting, and the facts as to the organic sources and the geological conditions necessary for their existence are concisely yet convincingly set forth.

The volume is altogether one that is remarkable for the mass of detailed facts both historic and scientific which it presents bearing on this industry in Ohio, and for the reserve and modesty with which its conclusions are drawn. N. H. W.

United States Geologic Map. Cottonwood Falls (Kansas) Folio (No. 109.). CHARLES S. PROSSER and J. W. BEEDE.

This folio contains a geologic map and description of the various formations found in the Cottonwood Falls quadrangle in central Kansas. The formations belong in the upper and lower portions respectively of the Carboniferous and Permian systems. This region became classic in American geology more than forty years ago from the animated discussion over the question whether the rocks were of Carboniferous or Permian age.

A brief description of the formations was published by professor Prosser in December, 1902, in the *Journal of Geology;* but the folio contains a more detailed description accompanied by various sections. The descriptions are of general interest for in many cases they are not confined to the area of the quadrangle, but give the distribution and character of the more important formations from the quadrangle southward into the southern part of the state and northward to Nebraska. The following are some of the more important and interesting formations, especially from an economic standpoint. The Cottonwood limestone, which is a massive stratum about 6 feet thick, composed to a large extent of foraminiferal tests belonging to the genus *Fusulina.* This is the most valuable construction stone in Kansas, which apparently loses its marked lithologic character in the southern part of the state, but to the northward it has been followed into southeastern Nebraska. The Wreford limestone is the next higher massive one with a thickness of 40 feet, which in part is very cherty and is the lowest of the conspicuous cherty limestones of the "Flint Hills" region. Sixty to seventy feet higher is the Florence flint, 20 feet thick, succeeded directly by the massive Fort Riley limestone, which has a thickness of 40 feet and is extensively quarried at various localities in the state. This was one of the first Permian limestones to be named and described in the state and its distribution has been traced from southern Kansas into southern Nebraska. The highest of the conspicuous limestones is the Winfield, which generally contains numerous large concretions that weather to a rusty color, and it forms a marked stratigraphic horizon across central Kansas.

The line of division between the Carboniferous and Permian systems is drawn with a query at the base of the Wreford limestone, which is identical with the horizon selected by Dr. Frech for the line of division between these two systems. Following the Washington meeting of the International Congress of Geologists Dr. Th. Tschernyschew, the noted Russian geologist, studied the Kansas river section from Manhattan to Junction and later published the following statement: "The layers of the Neosho, and perhaps the lowest part of the Chase [the Chase consists of the Wreford, Matfield, Florence, Fort Riley, Doyle and Winfield formations] appear to be analogous to the Schwagerinen [the upper stage of the unquestioned Carboniferous] in Russia, while the remaining part of the Chase and the layers of the Marion one must recognize as strata homotaxial with the Russian Permo-Carboniferous and lower Permian."

In a paper published nine years ago in the *Journal of Geology* by professor Prosser, the provisional line of separation between the Carboniferous and Permian systems was drawn at the top of the Florena shales in the lower part of the Garrison formation, 130 feet below the base of the Wreford limestone, which is very near the horizon that at a later date has been selected by the European authorities for the line of division between these two systems.

The folio also clearly shows the unexpected folding which the rocks of this quadrangle have undergone. Attention was first directed to this folding by professor Prosser in 1894, which had been overlooked by other geologists who supposed that the rocks of central Kansas had a nearly uniform dip of small amount to the northwest. In an earlier section along the Cottonwood river the geologist failed to recognize the reappearance of the Cottonwood limestone in ascending the river, due to an anticlinal fold, and so it was given a new number and regarded as a distinct and higher limestone.

Radio-Activity BY E. RUTHERFORD, MacDonald Professor of Physics, McGill University, Montreal. University Press, Cambridge, 1904. 399 pp.

Amidst the flood of papers, often immature and incomplete, relating to radio-activity, which have appeared within recent years, it is a distinct pleasure to meet with one in which the subject is treated in a comprehensive as well as calm and judicial manner. In the work issued under the above title professor Rutherford has brought together the available information relating to the so-called radio-active minerals in the form of a somewhat brief summary of twenty-seven pages. The remainder of his book is given up to a discussion of the Ionization Theory of Gases; Methods of Measurement; Nature of the Radiations; Rate of Emission of Energy; Properties of the Radiations; Continuous Production of Radio-active Matter; Radio-active Emanations; Excited Radio-activity; Radio-active Processes; and Radio-activity of the Atmosphere and of Ordinary Materials. Abundant references and footnotes serve to make the book a very satisfactory bibliography of the subject.

Incidental reference may be made to an earlier work by Dr. Philip Browning, of Yale University, entitled An Introduction to the Rarer Elements, which forms a very convenient supplement to the work of Rutherford, above noted. This last, aside from giving a brief historical sketch of each of the so-called rare elements, mentions the natural minerals in which it occurs, the typical compounds formed, their properties, and method of extraction. G. P. M.

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On new and old Middle Devonic Crinoids. (Smith. Misc. Coll., vol. 2, pp. 56-85, 1904.)

PERSONAL AND SCIENTIFIC NEWS.

MR. L. J. HARTZELL has been appointed to a professorship in the Montana School of Mines at Butte.

PROF. J. E. TODD is doing field work for the United States Geological Survey on the Redfield and Byron quadrangles in South Dakota.

DRS. J. W. BEEDE AND E. H. SELLARDS spent the summer in the field studying the invertebrates and plants of the Upper Carboniferous and Permian rocks for the University Geological Survey of Kansas.

DR. CLARENCE L. HERRICK, formerly one of the editors of the American Geologist, died Sept. 15, at Socorro, New Mexico, of tuberculosis. In a future number a suitable biographical sketch will be published.

THE HUGH MILLER MEMORIAL INSTITUTE was opened Aug. 26 by Andrew Carnegie. It is at Cromarty, and the origination was due to the memorial celebration held at Cromarty in 1902. The institute promises to be permanent and useful.

THE PALEONTOLOGICAL LIBRARY OF THE LATE PROF. C. E. BEECHER of Yale University, is for sale. It comprises over 3000 pamphlets and 200 volumes. Those desiring further information should write Prof. Charles Schuchert, Yale Museum, New Haven, Conn.

DR. A. C. LANE, STATE GEOLOGIST, has been engaged as non-resident lecturer to give two lectures a week on economic geology at the University of Michigan. This is a part of the work that belonged in the department of the late professor W. H. Pettee.

THE KEEWATIN GREENSTONE was struck by a deep well at Veblen, in Marshall county, South Dakota, at a depth of 860 feet. A sample of the drill-core showed a much squeezed rock carrying a considerable fine-grained or "chalcedonic" quartz. This formation gave a flow of soft water.

WE LEARN THAT PROFESSOR DR. J. F. POMPECKJ, long associated with the late professor von Zittel, is to leave the Alta Akademie at Munich, having accepted the chair of geology in the Landwirtschaptlichen Hochschule at Hohenheim near Stuttgart. We understand no chair of paleontology was established at Munich, but only one for geology, now occupied by professor Rothpletz.

MR. O. A. PETERSON, who has been making explorations for the Carnegie museum of Pittsburg, in the northwestern part of Nebraska and in Wyoming, made a somewhat prolonged field examination of the curious fossils known as Daimonelix. In a preliminary paper (*Science*, Sept. 9, 1904) he states that he believes from the facts noted that there is but little room to doubt that Daimonelix is cast of the burrow of a rodent. The skeletons of numerous rodent specimens were found entombed in the giant coils.

THE DEEPEST OIL OR GAS WELL IN THE UNITED STATES was completed in 1898 on the William Bedell farm at West Elizabeth, 12 miles southwest of Butler, Pa. It is 5,575 feet deep. A 10 inch casing was used to 40 feet, an 8.25 inch to 360 feet, a 6.25 inch to 1320, and from thence to the bottom is a 6.25 inch hole. Record was kept of the geological formations, the hole starting in the Carboniferous, 150 feet below the horizon of the Pittsburg coal and ending in a black shale supposed to be the Marcellus shale of the middle Devonian. Prof. Hallock, of Columbia University, made some careful tests of the temperature. At 525 feet the temperature was 57 deg. Fah., at 2252 feet 64 deg.; at 2397 feet 78 deg.; at 5010 feet 120 deg.; and at 5380 feet 127 degrees, an increase with depth of about 1.4 deg. per 100 feet. An accident left the tools and 1000 feet of the cable in the well, plugging it, or it would have been drilled deeper. (*Eng. Min. Jour.*)

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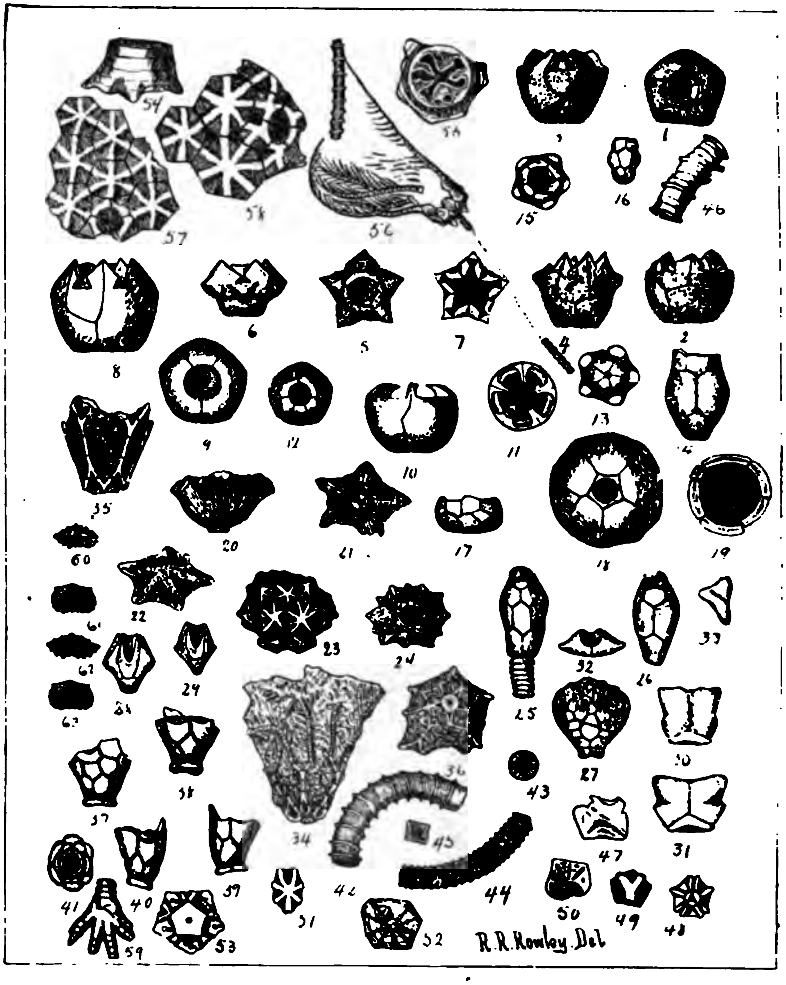

THE ECHINODERMATA OF THE MISSOURI SILURIAN AND A NEW BRACHIOPOD.

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ASTOR, LENOX AND
TILDEN FOUNDATIONS.

THE
AMERICAN GEOLOGIST.

VOL. XXXIV. NOVEMBER, 1904. No. 5.

THE ECHINODERMATA OF THE MISSOURI SILURIAN AND A NEW BRACHIOPOD.

By R. R. ROWLEY, Louisiana, Mo.

Pisocrinus granulosus, n. sp.

PLATE XVI. FIGS. 1, 2, 3 × 2.

The five basal plates of this little crinoid are quite large, extending considerably beyond the columnar pit. As in other species of the genus, they differ much in size and shape. The two large radials rest on the basals, the three smaller ones being triangular and lying between the two larger. The two posterior radials rest upon a rather broad, pentangular anal plate. The radial extensions upward, separating the arm bases, though not long, are stout as in the figures. The entire surface of the plates is beautifully granular. The plates are heavy and the body outline hemispherical.

Figure 3 in its plate arrangement differs widely not only from the specimen Figs. 1 and 2 but even from the genus Pisocrinus. However we take it to be a mere abnormality. Three of its radials are large and rest on the basals, while the other two are small, resting between the two larger radials without touching the basals. There is no anal plate, whatever.

In all the specimens of Pisocrinus figured on our plate the basal region is excavated.

The specimens came from the red, shaly limestone of the Niagara age, near St. Mary's, Ste. Genevieve Co., Mo.

Pisocrinus gorbyi ? S. A. Miller.

PLATE XVI. FIGS. 4, 5, 6, 7 × 2.

This is another granulose species, somewhat smaller than the former, distinctly star-shaped and less rotund. In small speci-

mens the radials are strongly pointed and give rise to a distinct constriction near their bases, as is seen in figure 6, a side view. The basals are five, irregular in size and shape and extend outward beyond the basal funnel. The line bounding the funnel is rather sharp instead of rounded as in *Granulosus.* Two of the radials are large and rest on the basals while three are much smaller, triangular and lie between the lateral sutures of the other two. The posterior paired radials are separated from the basals by a broad pentangular anal plate. The radial processes are large and abnormally broad, leaving but a narrow shoulder for the arm base. Some of the specimens of this and the succeeding species seem to be without basal plates or they have been very small and removed with the stem base. See Figure 9. These fossils differ some from Miller's types.

Specimens from the same formation and locality as the last.

Pisocrinus globosus? Ringueberg.

PLATE XVI. FIGS. 8, 9 × 2.

There is some doubt about the correct identification of this species, and in case it should prove to be distinct, it might be called *Pisocrinus sphaericus.* Specimens of this species are smooth and the largest collected at the St. Mary's locality. The basal pit is a rather broad inverted funnel with a rounded boundary below. The basal plates if present are very small and concealed beneath the top stem joint. They have probably been removed from the bottom of the pit. The radials as in the above species are five, two of them reaching the basals and the other three much smaller and mere wedges between the two larger radials and a broad anal piece. The radial processes are broad and leave less than half of the radial width for the attachment of the arm.

Horizon and locality same as the last.

Pisocrinus glabellus, n. sp.

PLATE XVI. FIG. 10, 11, 12 × 2.

This is another smooth species and differs from the last species in the possession of rather large basals and very narrow radial processes, thus leaving room for broad arm bases. The basal pit is rather large and with a sharp boundary above. The five basals form a triangle that extends beyond the pit. Two of the radials rest upon the basal triangle; one a small

triangular piece lies like a wedge between the two larger ones, hardly extending half the length of the body, downward. The other two are adjoining and rest upon a rather broad azygous plate.

Horizon and locality same as the last.

Cyathocrinus? ovalis n. sp.

PLATE XVI. FIG. 13, 14, 15, 16 × 2.

This species is almost certainly not Cyathocrinus. Our material consists of four, small oval bodies, all of which are figured on the plate. The stem scar is minute. The under basals are five in number, quadrangular and elongate forming a cup of considerable depth. The basals are five, elongate and hexagonal. The third ring of plates consists of five radials and an anal interradial of somewhat smaller size than the radials. The plates of this third ring are a little broader than long.

The diameter of the calyx through the middle of the basals is much the greatest lateral diameter, the radials tucking in toward the arm region and thus giving an oval form to the calyx. All of the plates are smooth and rather heavy (thick). The scar for the arm base is nearly the full width of the radial. Thebasals are considerably convex about their centers, giving a pentagonal outline, in an end view of the body. See figures 13 and 15. This lobed character even extends to the under basals but less so than in the basals.

Horizon and locality same as the last.

Lecanocrinus hemisphericus, n. sp.

PLATE XVI. FIGS. 17, 18, 19 × 2.

The excavation for the stem base is small and shallow.

The underbasals form a flat pentagon around the basal excavation and are small and 3 in number. The five basals are large, as broad as long and three of them pentagonal while two are hexagonal. The radials are five in number, broader than long and pentagonal in outline. The arm base occupied the entire width of the upper radial edge. Lying between the upper sloping edges of two adjoining radials and the lower edges of a radial and second anal piece is a small quadrangular first anal. The second anal lies between two radials, the first anal and the upper sloping edge of a basal and extends a little above the top of the radials.

The greatest width of the calyx is a little below the top of the radial ring. There is little convexity to the plates. The surface of all the plates is very finely granular and scarcely discernible low ridges pass from plate center to plate center.

Locality and horizon same as the last.

Cordylocrinus? dubius, n. sp.

PLATE XVI. FIGS. 20, 21, 22 × 2.

This little crinoid has much the appearance of Macrostylocrinus both in outline and ornamentation, but differs in the shortness of its costals, anchylosis of its basals and the presence of but one interradial to the area on the doral side.

There is no basal excavation for the column but a slight elevation, almost a rim. The columnar canal is apparently round and minute. The use of a lens and a strong light fail to disclose interbasal sutures. It is therefore probable the basal plates are anchylosed, forming a broad but not deep cup.

Five large radials, breader than long, rest upon the basals.

Near the top of the radial there is a thickening of the test that throws nearly half of the radial width into a fold forming a lunular scar above on which rests a short, very small, quadrangular first costal. Of less width and no greater length is the second costal, a bifurcating plate. The upper part of the depressed area between the radial folds is occupied by a single anal plate that bends over on the ventral side.

The dorsal plates are ornamented by fine lines that follow the basals and radials longitudinally and cross the depressed areas from radial lobe to radial lobe. One-half of the dorsal surface is preserved and is composed of rather strong ambulacral ridges and depressed triangular interambulacral areas made up of a few plates. The ambulacral plates are small and apparently form double series.

The anal area differs little from the interradial spaces, with no apparent difference on the dorsal surface. There is no apparent ornamentation on the interambulacral spaces but the ambulacral ridges seem to be corrugate.

Locality and horizon same as the last.

Stribalocystis missouriensis Rowley.

PLATE XVI. FIGS. 23, 24.

This little cystoid was described in the *American Geologist* for February, 1900, page 71, and figured on plate II. (Figs. 40, 41). There is an excavation in the basal plates for a medium size, round column with a central canal, apparently round. Of the four plates of the basal ring the larger two are pentagonal and the smaller two quadrangular. Resting upon these four plates is a ring of six larger ones, two of which are pentagonal, two hexagonal and two heptagonal. These are variable in size, the pentagonal being smallest. There are eight plates in the next ring and about sixteen smaller ones in the ventral disk.

There is a small anal opening near the edge of the disk and six or seven other small perforations just above the third row of calyx plates. Around four of these latter canals are surfaces apparently for the reception of arm bases. All of the plates are quite convex and ornamented by strong radiating ridges or a central node and ridges.

Figure 23 is a side view of the type specimen and figure 24 a basal view of a much smaller specimen.

Locality and horizon same as the last.

Stribalocystis? elongatus Rowley.

PLATE XVI. FIGS. 25, 26.

This little cystidean is almost certainly not stribalocystis. The only two specimens collected are imbedded in the limestone in such a way as to make uncertain the number of plates to the ring.

There are either three or four elongate basal plates, four or five in the second ring, five or six smaller plates in the third row, six or seven still smaller ones in the fourth row and a number of small crown plates.

Neither of the specimens show any openings, pectinated rhombs, or appendages except a short piece of the column. The stem is quite large and the part attached to one of the specimens has seven joints as in figure 25.

This species was described in the February, 1900, AMERICAN GEOLOGIST, page 71 and figured on plate 2 (figure 39).

Collected from the Delthyris limestone at Red Rock Landing, Perry Co., Mo.

Melocrinus wittenbergensis, n. sp.

PLATE XVI. FIG. 27.

The only specimen collected is small and injured on one side. The color is quite black.

The four basals form a short neck. The first radials are a little wider than long, and hexagonal. The second radials or first costals are wider than long and pentagonal. The second costals are wider than long, pentagonal and bifurcating, supporting above a double series of two distichals each to the arm bases, or rather brachial rays. There is very little difference in the size of any of these radial plates. There is a single heptagonal interdistichal plate. The lowest interbrachial rests between the sloping upper edges of the radials and the lateral edges of the costals and is seven sided. Above this latter are two other interbrachials, somewhat smaller, or three interbrachials in all.

The azygous side is injured so that no diagnosis can be made of the anal interradius. The plates of the ventral disk are quite large and each has a short central tubercle. The plates of the dorsal side have little convexity, the costals, under a magnifier, having the appearance of an ill defined central tubercle.

The anal tube or opening is broken away in the specimen. There is a slight basal excavation for a rather strong column.

Delthyris limestone, a mile and a half below Wittenberg, Mo.

Troostocrinus? dubius Rowley.

PLATE XVI. FIGS. 28, 29.

This little blastoid was figured and described in the February, 1900, number of the AMERICAN GEOLOGIST. (Plate 2, Figs. 36, 37, 38.)

The three basal plates form a triangular, pyramidal cup. Hight and width about equal. The radial sutures apparently extend to the top, as no interradials are visible externally. The top of the anal interradial area projects somewhat above the tops of the other areas in some of the specimens. Except the anal opening and the central uncovered area, no other openings are visible.

The ambulacra are over a third of the length of the entire body and lie a little below the edges of the radial lips. The

number of pore pieces on either side of the lancet in each area is from fifteen to twenty.

No columnar cicatrix can be seen on any of the nine specimens and if present, the stem must have been very slender. We have a strong suspicion that it had no stem. The ornamentation of the plates is fine parallel striae.

Horizon and locality same as the last.

Calceocrinus alleni, n. sp.

PLATE XVI. FIGS. 30, 31, 32, 33.

The two smaller basal plates of this species are shown in figure 32. The columnar excavation is shallow and the columnar canal small and apparently round. The third basal is shown in both figures 30 and 31. As usual it is nearly as broad as the body and short, forming a gaping suture with the two smaller plates. The two latteral radials are large and bend upon the posterior side, but do not apparently meet and separate the two anterior radials. The lower anterior radial appears to be quadrangular instead of triangular. The upper plate is wanting in our specimens, but was undoubtedly quadrangular with its short side resting on the upper short side of the post-anterior radial. This arrangement seems to make the lateral radials pentagonal. Arms and column unknown. Surface apparently smooth.

This interesting crinoid is named specifically for my friend, the collector, Mr. Thos. W. Allen, of St. Joseph, Mo.

The types were collected from the Clinton division of the Niagara Limestone at Watson Station, Pike Co., Mo.

Glyptocrinus insperatus, n. sp.

PLATE XVI. FIGS. 34, 42, 43.

From the round stem base, five folds or rounded ridges pass out almost horizontally to the centers of the five rather large basal plates. Folds of similar strength extend from the centers of the basals to the centers of the radials, forming five broad, inverted V's, a single strong fold or ridge following the remaining radial area to the center of the second costal, bifurcating there and passing into the arms.

The center of each interradial plate is occupied by a small tubercle from which radiate six or more delicate ridges to adjoining plates. The radials are pentagonal, the first costals hexagonal, the second costals pentagonal and axillary.

There is little difference in the size of the radials and costals. There are three distichals above the axillary second costal to where the wedge shaped arm pieces begin.

Arms, rounded, continuations of the radial folds and composed of a single series of wedge-shaped pieces that give off alternately rather long, slender pinules whose joints are long and grooved on the ventral side rather deeply. The pinules near the base of the arms are much stouter. The interradial areas somewhat depressed and each filled by a series of 1, 2, 2, etc. plates, the lower and larger one of which is hexagonal and lies between the first costals, its lower angle filling a shallow V between the upper edges of the radials.

Ventral surface unknown. Infra-basals, if present, not visible beyond the stem base. Arms apparently long and ten in number.

Column round with every third or fourth joint much wider than the rest.

Locality and horizon: two and one-half miles northeast of Edgewood, Pike county, Mo., and from an earthy limestone of the age of the Clinton group.

Glyptocrinus insperatus var. pentagonus, n. var.

PLATE XVI. FIGS. 35, 36.

This fossil is somewhat larger than the preceding one with much stronger radial folds or ridges and more distinct stellate ornamentation of the plates, especially the interradials. A fold, quite as strong as the radial ones, passes up the middle of the anal area from the center of a basal. The five double folds of the basal region form a flat star and the inverted V's formed by folds from the centers of the radial to the centers of the basals together with the rays of the basal star bound deep diamond-shaped areas.

The interradial areas are flat, the anal interradius being broader than the other four. The plate arrangement is exactly as in figure 34. Fine granules cover the surface of the plates.

The specimen preserves the calyx to the top of the second costal which is a bifurcating plate and there are perhaps but ten arms.

The columnar base is round and the perforation rather small. Four of the basal plates are perhaps pentagonal (in

the absence of infrabasals) and one hexagonal. The radials are larger than the basals and heptagonal. First costals hexagonal. Second costals pentagonal.

The first interbrachial is hexagonal and followed above by two smaller plates. No higher plates are found on the imperfect type specimen. A large hexagonal first anal is succeeded by three plates above, the middle of the anal area being traversed by a strong fold or ridge. The granular surface character, the absence of central nodes and the very strong radiate ornamentation and ray folds may be sufficient to separate this crinoid specifically from the former species. If so, the proposed varietal designation may become the name of the species.

Were it not for the fewness and size of the interbrachial plates, both this and the previously described species might be referred to Ptychocrinus W. & Sp. (Gaurocrinus, S. A. M.).

Horizon and locality same as the last.

Gissocrinus? problematicus, n. sp.

PLATE XVI. FIGS. 37, 38, 39, 40, 41.

Under basals three, of nearly equal size and forming a slight rounded rim below the basals. Two of them are five and the third four-sided.

The anterior one is longer than either of the other two.

The basal plates are large and a little longer than wide, the posterior being heptagonal and truncate above to receive the first anal plate. The basal to the right of the posterior is also heptagonal while the one to the left is pentagonal. The right anterior basal is hexagonal and the left pentagonal.

Two of the radial plates are much larger than the basals while three are of about the same size and one smaller. The large radials are the anterior and the one to the left of it. The one to the right of the anterior has its upper edge below that of the other radials. The posterior radials rest between the sloping upper edges of basals a little more deeply than the others and are smaller, the one on the left of the anal area supporting above a costal of greater width, partly resting on the first anal. The small radial to the right of the anal area supports above a costal of greater length and width partly supported by a basal.

The lunular scar for the reception of the first costal on three of the radials and on the first costal for the reception of the second costal of two of the rays are less than half the width of the plates. Supported by the first anal plate which is hexagonal of equal width and length and lying above a truncate basal and between two radials and the two costals, is the second anal of equal size and shape as the first and lying partly between the two costals. The surface of all plates is apparently smooth.

The column was perhaps as wide as the underbasal rim and with a medium canal. Arms and ventral surface unknown.

In the equal underbasals, the number of anal plates and the incorporation of two first costals in the calyx, this little crinoid seems to differ quite widely from Gissocrinus and, in fact, all other cyathocrinoids. Its nearest affinities, however, seem to be with the cyathocrinoids and the genus Gissocrinus. Anomalous as the statement may seem, the two costals mentioned in the description have every appearance of radials except as to location.

The specimen came from the oolitic division of the Clinton group, three miles west of Louisiana, Mo.

Glyptocrinus insperatus? var carinatus, n. var.

PLATE XVI. FIG. 56.

This little crinoid, imperfect as it is, lying half imbedded upon a slab, has the appearance of being congeneric with figs. 34, 35, 36 and possibly, co-specific, agreeing with the three in its long slender pinules and the character of its stem, but differing in the possession of strong keel-like nodes on its basal plates. The portion of stem attached to the base is composed of thin, uniform, round rings. An inch away every third or fourth stem joint is broader than its fellows, as shown in the figure. Better specimens may show this form to be a good species. Of the body plates but little can be made out beyond the fact that there are five keeled basals and five larger radials with a central indistinct ridge, each.

The portion of a larger stem lying among the arms is of a larger specimen and shows well the character of the associated columns.

The specimen comes from the Clinton beds three miles northeast of Edgewood, Pike Co., Mo.

Lampterocrinus? comptus, n. sp.

PLATE XVI. FIGS. 57, 58.

The specimens of this crinoid are so fragmentary as to render a description more or less imperfect. Detached plates are not uncommon but perfect bodies are not known. The two specimens figured preserve enough to show that the species had a slight basal rim about a shallow stem cicatrix, five basals and five larger radials, with two costals to the ray. The regular interradials are in series of 1, 2, etc. and the anal area of 1, 3, etc. Radiating ridges cross from center to center of adjoining plates.

The specimens are from the Clinton oolite three miles west of Louisiana, Mo.

CRINOID STEMS.

PLATE XVI. FIGS. 42, 43, 44, 45, 46.

The stem represented by figs. 42, 43 is that of a Glyptocrinus, perhaps, as also the specimen near the top of the page, differing none from the lower part of the stem belonging to fig. 56, except in size.

Figure 46 is a related stem but coming from the oolite west of Louisiana while 42 and 43 are from the earthy Clinton beds near Edgewood.

44 and 45 are doubtless a Mariacrinus stem associated with 42 and 43.

CRINOID STUMPS.

PLATE XVI. FIGS. 54, 55, 59.

The figures 54 and 55 are of a specimen from the red and yellow-banded Niagara limestone of Ste. Genevieve Co., Mo. The specimen is without roots, being merely expanded below.

Fig. 59 is from the same horizon and locality and possesses roots.

CRINOID BASES.

PLATE XVI. FIGS. 48, 53.

Figure 48 is composed of three basal plates with sutural ridges and a round protuberant stem base. From the Clinton oolite, three miles west of Louisiana.

Figure 53 has apparently five basals and a pentagon stem base. The plates are ornamented by small nodes an ridges bordering the sutures. From the Niagara of Ste. Genevieve county.

CRINOID PLATES.

PLATE XVI. FIGS. 49, 51.

These plates perhaps belong to some species of Lamptero-crinus. Clinton oolite, Pike Co., Mo.

CYSTOID PLATES.

PLATE XVI. FIGS. 47, 50, 52.

These are found associated with the crinoid plates above. A single plate of Caryocrinus *ornatus* was found at the St. Mary's locality, but the writer failed to find Edriocrinus in the Delthyris beds at Red Rock Landing.

Skenidium? nodocostatum, n. sp.

PLATE XVI. FIGS. 60, 61, 62, 63.

This little shell has some external resemblance to Orthis. However, the few, strong plications, rather high cardinal area and other features separate our species from that form and, as it bears a strong resemblance to Skenidium we have ventured to place it under that genus, in the absence of structural material.

The cardinal area is less than the width of the shell, not high and with an uncovered deltidium whose sides are almost parallel. The brachial valve is somewhat convex with a broad illy defined sinus occupied by two plications smaller than the ones bounding the area. Either side of the sinus is covered by three strong plications with three other smaller implanted ones, not reaching the beak.

The pedicel valve is slightly more convex than the brachial without fold, but with a strong central plication. Either side of this central costa are three strong ribs or plications with an equal number of smaller implanted ones as on the brachial valve.

The beak of the brachial valve protrudes beyond the cardinal area of the pedicel valve, displaying a narrow brachial area. The beak of the pedicel valve is almost retrorse.

The transverse lines of growth are strong and give to the ...ations where they cross, a nodose appearance. The shell is distinctly bilobed.

From the Niagara limestone, six miles west of St. Marys, Mo. The ...ll is rare and the collection contains but three specimens, two of ...ich are figured.

Found associated with Pisocrinus granulosus and Stribalocystis ...issouriensis.

EXPLANATION OF PLATE XVI.

PISOCRINUS GRANULOSUS, N. SP.

Figs. 1 and 2. Basal and anal side views of the type, two diameters.
Fig. 3. An aberrant specimen, side view × 2.

PISOCRINUS GORBYI? S. A. MILLER.

Fig. 4. Side view of a large specimen, two diameters.
Figs. 5, 6, 7. Basal, side and top views of another specimen × 2.

PISOCRINUS GLOBOSUS? RINGUEBERG.

Fig. 8. Side view of a large specimen × 2.
Fig. 9. Basal view of another specimen × 2.

PISOCRINUS GLABELLUS, N. SP.

Fig. 10. Side view of a very large specimen × 2.
Fig. 11. Top view of a smaller specimen × 2.
Fig. 12. Basal view of a small specimen × 2, showing large basals.

CYATHOCRINUS? OVALIS, N. SP.

Figs. 13, 14, 15. Basal, side and top views of three different specimens x 2.
Fig. 16. Side view of a small individual, two diameters.

LECANOCRINUS HEMISPHERICUS, N. SP.

Figs. 17, 19. Side and top views of two small specimens × 2.
Fig. 18. Basal view of a large example, two diameters.

CORDYLOCRINUS? DUBIUS, N. SP.

Figs. 20, 21, 22. Lateral, dorsal and ventral views of the type × 2.

STRIBALOCYSTIS MISSOURIENSIS ROWLEY.

Fig. 23. Side view of the type, natural size.
Fig. 24. Basal view of a small specimen × 2.

STRIBALOCYSTIS? ELONGATUS ROWLEY.

Fig. 25. Side view of the type specimen, natural size.
Fig. 26. Side view of another specimen, natural size.

MELOCRINUS WITTENBERGENSIS, N. SP.

Fig. 27. Side view of the type, natural size.

TROOSTOCRINUS? DUBIUS ROWLEY.

Figs. 28, 29. Side views of two large specimens, natural size.

CALCEOCRINUS ALLENI, N. SP.

Figs. 30, 31. Side views of two different individuals, natural size.

Fig. 32. Basal view, showing columnar excavation and two basal plates × 1.

Fig. 33. Side view of another individual, natural size.

GLYPTOCRINUS INSPERATUS, N. SP.

Fig. 34. Side view of a specimen preserving the arms and pinules × 1.

Figs. 42, 43. Side and end views of a column, probably belonging to this species, natural size.

GLYPTOCRINUS INSPERATUS VAR. PENTAGONUS, N. VAR.

Figs. 35, 36. Side and basal views of the type, natural size.

GISSOCRINUS? PROBLEMATICUS, N. SP.

Figs. 37, 38, 39, 40, 41. Side and basal views of the type specimen, natural size.

Figs. 44, 45. End and side views of a quadrangular stem belonging to some species of *Mariacrinus,* associated with 34, 35, 42, × 1.

Fig. 46. A stem from the Clinton oolite, associated with 48, 49, 50, 51, 52, × 1.

Figs. 49, 51. Crinoid plates from the Clinton oolite, nat. size.

Fig. 48. The three plate basal ring of a crinoid, nat. size, associated with 49, 51.

Figs. 47, 50, 52. Plates of Cystids, nat. size, associated with 48, 49, 51.

Fig. 53. Base of a Crinoid from the Niagara of Ste. Genevieve Co., nat. size.

Figs. 54, 55. Side and top views of a Crinoid stump from the Niagara, of Ste. Genevieve Co., nat. size.

Fig. 59. Side view of a Crinoid stump with roots. Niagara, same locality, nat. size.

GLYPTOCRINUS INSPERATUS? VAR. CARINATUS, N. VAR.

Fig. 56. View of the type as it lies imbedded on a slab, nat. size. The dotted line connects the top of the stem with another fragment about an inch away, the intermediate portion having been destroyed by some agency.

LAMPTEROCRINUS? COMPTUS N. SP.

Figs. 57, 58. Basal views of two specimens, preserving portions of the calyx. Natural size.

SKENIDIUM? NODOCOSTATUM, N. SP

Figs. 60, 61, 62, 63. Cardinal, pedicel, anterior and brachial views of the two type specimens, natural size.

TECTONIC GEOGRAPHY OF EASTERN ASIA.

Reviews and Translations by WILLIAM HERBERT HOBBS.

IV. JAPAN* (SECOND PAPER).

C. THE STRUCTURE AS A WHOLE AND THE LINES OF DISLOCATION.

In the two preceding sections of this paper, were treated individual parts of the two wings of Japan; in the two following will be considered such phenomena as are common to the two wings or concern the island country in general.

The Great Transverse Fracture. In the vicinity of the 138th degree of east longitude there appears to one who approaches from the east, a series of striking phenomena following in rapid succession, and these cause an important change in the landscape. First there are the fragments of the walls of an extended kettle-like sinking in the ancient range, from the middle of which the beautiful cone of Fuji-yama rises to a hight of 3728 meters; then the distinct series of well preserved volcanic cones in the straight line of Fuji-Yatsugadake; further the kettle of Kofu, sunk into the granite of the Kimposan, which rises to 2550 meters. But the rarest surprise is furnished on the west side of the road leading from Kofu to Suwa lake by a rectilinear high wall above which becomes visible in the west somewhat later the granitic Komaga-take rising in the immediate neighborhood to the hight of 3000 meters; and by the observation that here steeply uplifted ancient schistose rocks are in place with almost meridional strike, while to the eastward from Kofu the dominating equatorial strike direction was recognizable within a somewhat confused complex.

It is obvious that that stretch of road follows a great fracture of the crust. The geological map allows us to now easily recognize its course in detail. Westward from Fuji it is exactly meridional in a stretch of 88 km from the coast city of Schidsuoka to Nirasaki which lies westward from Kofu; then it follows for 72 kilometers the direction N 42° W until west of Matsumoto. From here to the north coast (90 k. m.), it runs again meridionally, but in a flat arc concave to the eastward. The entire length of the line is, therefore, 250 kilometers.

The following phenomena are connected with this line:

1. in a purely morphographic sense the line indicates the limit of a steep wall and a furrow reaching from sea to sea. If the bottom of the latter does indeed rise in the vicinity of Suwa lake to above 800 meters, it is none the less an important line of commerce.

2. The fundamental complex of the entire country lies deeper in the east than in the west. Here is the wall of the steep break in the highest upbulging of the land mass of Japan, toward which the fundamental complex, with its granites, gradually rises from the west,

* **In the last paper of the series (this journal September, 1904) was begun a translation of the fifth paper by V. RICHTOFEN in his studies of the geomorphology of east Asia.**

so that in the Kisso range and in the Hida range it reaches its great-est elevation in the vicinity of that descent. On the east side the basement vanishes at once, completely covered by later deposits, and where it becomes visible again in the Kwanto range and farther to the north, it rises only rarely to a little more than 2000 meters. Even the granite domes, which in reference to the relations of altitude have an independent position, are lower than those of the west. Harada has called attention to the regional value of these differences in eleva-tion.

3. The fracture line cuts off diagonally the strike directions of the western ranges in the principal stretch from Nirasaki to beyond Matsumoto, under angles of 40° to 60°; in the two N-S stretches, how-ever, it is approximately parallel to them; it is as if it were deflected in sections by the lines of the internal structure, as is so often the case with continental arcs of the plateau borders.

4. To the eastward from the fracture, the strike directions of the western ranges do not again appear. All observers agree in this that in the Kwanto range, in spite of many irregularities, the direction NW-WNW is to be considered the normal one. A bending around of the strike from one side to the other it has not been possible to prove, since the connection is interrupted. It is also in itself not probable because to the north of the Akkaischi-yama a bending back of the beds occurs from N by E to N. Further, the gneiss band of the north zone, in which the Tenriu-gawa flows, is no longer visible upon the east side.

5. A support for a determination of the time of the sinking in it is not yet possible to obtain; since the circumstance that the entire north wing of Japan, from the great fracture line to the borders of Abukuma and Kitakami, is covered over with heavy marine Tertiary deposits of Miocene and Pliocene age, whereas they are restricted in the west of the fracture line to the coasts and lower-lying portions, does not suffice; and from the distribution of the Trias, as well as portions of marine and in part continental development of the Jurassic and Cretaceous, certain conclusions are not yet to be drawn. The analogy also with the numerous meridional fractures of east Asia for which in general the beginning probably occurred in early Mesozoic time, and further development in later periods, cannot be here ap-plied, since this fracture furnishes in comparison with the others, much that is peculiar.

The Volcanic Series of Fuji and the Line of Islands in the Bonin Ridge. The volcanic series of Fuji stretches to the eastward of the great cross fracture transversely through Hondo, furthermore not in a straight but in a broken line. The mean direction can be regarded as parallel to that of the cross fracture; but this does not hold true for the individual sections of both lines. According to the present view of the Japanese geologists, the Fuji volcanic series begins in the north with the group of Mioko-san, whose peak is distant 26 kilometers from the coast. The line runs from it S 10° E to the Tates-

china-yama (2530 m.), distant 90 kilometers; from it a line of the series directed S 25° E touches the peaks Yatsugadake (2932 m.), Kayagadake (1240 m.), Fuji-yama (3728 m.), Aschitaka-yama (1187 m.), Amagisan (1386 m.), and reaches beyond the island of Niijima to the island of Myakejima, which is distant from Tateschina 255 kilometers. Here it meets a loxodromically straight line, likewise sharp, and directed from N 10° W, to S 10° E, which extends through young and generally very small volcanic islands characterized for the most part by present activity, in a length of 1,200 kilometers. Belonging to it are: O-schima (34° 44′ N), Miyakejima (34° 5′ N), and with for the most part greater intervals, seven small islands and reefs, to Ponafidin and Lot's Wife (29° 48′ N), then Rosario (27° 16′ N), and the volcanic islands stretching from 25° 25′ to 24° 18′. At a distance of 130 kilometers to the east rises the almost parallel series but yet slightly curving into an arc (convex to the sea) of the somewhat larger Bonin islands, 120 kilometers long, for which series the Japanese use the name Ogasawara-jima. Yoshiwara has found nummulitic limestone upon them. Based upon the interlamination of tufa and upon other phenomena, the conclusion has been drawn that here the volcanic activity has reached from the Eocene time into the Miocene, and since a subsequent elevation appears not to have occurred the entire series of islands must be considered as an older one in respect to that just mentioned.

Soundings have shown that the islands are raised above the submarine ridge which has been designated the Bonin Ridge. It is not certain whether it can be surrounded by the 2,000 meter line; yet it is probable that it extends southward to 20°N. Concerning its relations to the ridge of the Mariannes, no conjecture can yet be made.

The Great Japanese Volcano Arc (Bandai Arc). If the portions of the great continental framework which are above the sea, marked out by the Japanese islands, allow the internal connection and the history of their ancient basement to be made out but incompletely, certain lines of great disturbance in later time, which were connected with important neo-volcanic processes, are so much the more distinctly drawn. Among these new dominating lines (*Leitlinien*) which came into being in middle Tertiary time, that one is by far the most striking which is genetically connected with the volcanic arc here under consideration. It follows neither the direction of the strike nor of recognizable ancient fractures, nor does it show any dependence upon the deflections which the north zone and south zone of South Japan have been subjected to on their east end, but it intersects each of these elements at arbitrary angles. The tendency of the east Asiatic arcs which are convex toward the ocean, is, as was shown, not to be made out in any part of the fundamental complex; here in the great Bandai arc of volcanoes it holds true for the first time in a strict sense. The arc intersects North Japan in the *middle line* and is likewise marked out by massive volcanic formations as well as by basins depressed upon either side. If westward from Satporo, in Yezo, we

start out from Yoitschidake, which rises at the intersection of 140° E and 43° N, the series of volcanoes follows this meridian to the southward in great stretches; northward, also it has been attempted to extend them by two degrees of latitude to the volcano of the island of Rischiri, 1740 meters in hight. Southwards the series deviates to the west from the meridian for the first time, where it leaves the eastern environs of the Kitakami mountain country in order to go over westwards from Sendai and to the northern portion of the Abukuma mountain country. Here in Sao-san (1964m.) it has already reached 140½° E and has nearly attained 38° N. In the environs of the circular lake Inawaschiro above which the Bandai-san rises to a hight of 1960 meters, it is broadened out to a double series, of which the eastern one, runs SSW to Nasu (1912 m.), then southwest to Nan-tai-san (2483 m.), near Nikko, thereupon WSW to Akagi-san (1839 m.), and finally W by S to the Asama-yama (2480 m.). Here it has reached a longitude of 138° 35′ E, a latitude of 36° 25′ N, and comes into the immediate neighborhood of the Fuji series.

Thus apparently ends the beautifully curved arc. But at this end is joined a meridional cross series which is parallel to the northernmost stretch of the Fuji series and is distant from it 36 kilometers. Asama, Schirane (2253 m.), Iwasuge (2515 m.), Hennomine (1804 m.) and Ammamisu (1090 m.), are its peaks. It is more worthy of note that in the exact extension of the arc itself to the W by S beyond the Fuji zone and the great fracture rim lies the unique volcanic series in the great region of eastern South Japan. Norikura (3166 m.), Hakusan (2640 m.), Dainitschi (1236 m.), and Kunimi-dake (638 m.) mark it out. Kunimi lies upon the sea in the meridian of the Biwa lake 225 kilometers distant from Asama. The length of the entire volcanic arc from Rischiri is nearly 1300 kilometers.

The penetration of this arc across the great fault cleft into a differently constructed mountain country, reminds one of the penetration of the Aleutian arc into the central range of Kamtschatka, or of that of the Kurile arc into the Hidaka chain of Yezo, and of the Liukiu arc into the transversely directed structure of Kiusiu. As in the first case, so it appears also here, as if the reappearance in a foreign region were connected with special intensity of expression: for the Nurikura, like the Asama-yama, is the focus for a transversely directed series to which the Ontake (3185 m.), in the south and the Iwodake in the north belong.

The great volcano arc—which I will call from a generally well-known peak, the Bandai Arc—is for North Japan the real dominating line of the most recent time. As a chain of volcanic islands like the Liukiu, the Kuriles, and the Aleutian islands, it had appeared in connection with the sinking of the land beneath the surface of the sea. As a transversely facing continent, with steep and sharply cut eastern border, should rise the land lying to the west of the great fracture. On this the arc should advance in flanking position and continue running over across it. The similarity with the flanking

chains under consideration goes even further: for as in front of the place of contact of the Aleutian arc with the ancient continental mass of Kamtschatka, a line of high volcanoes runs to the SSW with an angle of 70 to 80° with the entering line, to be continued as a string of islands; so here the Fuji series of volcanoes, likewise continues immediately before the place of entrance with an angle of 80° to be extended in the ocean as a series of islands directed S 10° E.

If one considers the base from which the Bandai volcanic series rises, he recognizes that it is a sunken region. A fault margin accompanies this in the east and intersects the land without regard to the structure of the underlying rock, even if deflected at times by it for a distance. In the depression of Satporo upon Yezo, such incongruence is not yet observable. In Hondo to the westward of Kitakami and Abukuma the line of fracture coincides with the oft mentioned "median line," which, as was shown above, runs discordantly to the mountain structure and forms the natural trench for the commerce between south and north. The sunken region is covered over with young Tertiary sediments, rich in tuff, which in the water parting Bandai range compacted by volcanic rocks were overtopped from E to W in passes of 600 to 1000 meters, and show upon the map altitude figures to above 1,200 meters.

That still other recent vertical displacements have taken place has been indicated above: for the Tertiary deposits are lacking to the Kitakami mountain country; the Abukuma mountain country is accompanied by them near the coast. Each shows sunken areas through its Rias coasts: in the former country are evidences of negative translation of the coast line. Still more the character of local occurrences is in keeping with that of the basin depressions to the west of the divide, which are of importance for the form in detail. Like the latter, the individualized volcanoes which rise from kettle depressions on the west coast can here be considered only in passing.

Perhaps they belong to the volcanoes which have no immediate connection with extended fracture structures, but are built up over isolated chimneys.

D. General Scheme of the Mountain Chains of Japan.

We arrive at the following results:

1. The island of Shushima and the group of the Goto islands do not belong to the structure of Japan, but are to be considered as members of the Korean arc.

2. South Japan consists of two different independent ranges, namely: 1. An equatorially directed much degraded main body built up of gneisses and Paleozoic sediments folded in post-Carboniferous times and greatly intruded by probably post-Carboniferous granites, which main body [illegible] south, through which its eastern [illegible] suffered a sharp bending with S E convexity against a [illegible] 2. A [illegible] contiguous Mountain Zone [illegible] one band, consisting of folded [illegible]

ments with rare granite intrusions, whose folds originally striking in the Sinian direction (about W 30° S to E 30° N) were deformed by the southwardly migrated north zone to an arc convex to the N W and by internal compression has been soldered to the compressing range of the north zone along a long sharply drawn line. Where the latter experienced its sharp bending a nearly detached fragment of the south zone, the Akaishi range, was placed almost along the meridian side by side with the gneisses of the north zone, and now appears as if pressed in between the latter and the obstruction. In the north zone the inner (northern) portion suffered compression, the outer (southern) tension; hence we find in the former a compact frame work but irregularity of strike, in the latter regular strike but lateral opening, fracturing to horsts and sunken areas into which the sea penetrates in the form of bays which in part unite to form the interior sea. The granites appear to follow in part lines of fracture directed radially toward the outer zone. In the south zone on the other hand the outer (northern) portions of the arc were compressed, being crowded together upon a short line; they close up the bays of the north zone and have brought about the narrowness of the entrances to them. The granites of the north zone end abruptly at the border line.

3. The Equatorial main body is probably a continuation of the Tsinling-range, the Kuma-Kii range of an eastern member of the south Chinese mountain country. The arrangement of chains in the two ranges in South Japan corresponds to that which is the rule on the south side of the Tsinling. The Kuma-Kii range is a backwardly compressed arc soldered upon the lee side in the manner in which they there occur. A local deviation from the Chinese structure is conditioned by the dragged backward bending of the eastern part of both zones.

4. The position of the Nagasaki triangle is not to be determined since the observations at hand are not sufficient.

5. The fundamental structure of North Japan inclusive of Yezo, is characterized by the presence of three broad strongly folded rectilinear zones parallel to one another and striking in the direction N by W to S by E; which from the names of their parts which appear as independent mountain masses may be designated at the Hidake, Kitakami, and Abukuma zones. The latter consists of gneiss; in the structure of the two first mentioned Paleozoic share with (probably) Algonkian sediments.

In the portion of North Japan lying between the Abukuma zone and the great transverse fracture, the places where the underlying rocks come out from beneath the enveloping cover furnish at present no adequate support for a conclusion regarding the structure. In the hill countries of Kwanto, Aschio, Yamiso-Tsukuba, and Etschigo the basement consists of similarly folded Paleozoic schists and granites, to which in the Kwanto hill country the (Algonkian) Sombagawa stage is added. In the latter the strike is W N W, in the others it

varies so between northwesterly and northeasterly directions that no order is recognizable. The gneisses of Kino and Hida are here lacking; apparently only the elements of the Kuma-Kii zone are present, and it is not proven that detached portions of the latter do not have an essential part in the composition of the region in question due to tectonic fracturing on a large scale.

6. Two tectonic lines indicated by volcanoes invade from without the mass of Japan. The first of them is *a*, the Liukiu Line. It is connected with the Kuma Kii range as a prominent flank range. Its interior recognizable line beset with island volcanoes, shows its invasion in a meridional series of volcanoes transverse to the structure of Kiusiu and extends perhaps to beyond Asayama. The tectonic influence of lines which are parallel to the latter may be recognized in the abruptly terminated transverse coasts of southern Kiusiu. The second of the tectonic lines is *b*, the line of the Bonin ridge beset with the volcanoes of the volcanic islands, Bonin islands, Schitschito islands, and other numberless volcanic islands arranged in the direction S by E to N by W. In the continuation of the latter line deviated toward the N N W, rise the volcanoes of the *Fuji series*. The unusual significance of this chain for Japan may be recognized in many different phenomena. For not only does this series of volcanoes run through the entire island of Hondo throughout in its broadest place; it is also accompanied by a very important fault, which calls attention to the variety found in the plateaus (Landstaffeln) of the continents in this respect that the form of the land bordering upon the west noticeably ascends till it reaches the fault cleft and then an abrupt descent follows toward the deeper step; it appears, however, not to take place in step fractures, as is usually the case. A third matter of the utmost import is the *drag on the west side of the great cross fracture*. One cannot avoid Naumann's conclusion that where the depression has occurred a solid obstruction existed, which lay in the line of the Bonin ridge. This is strengthened by the consideration that the Bonin ridge with its no longer projecting northwestern continuation, as regards position and direction, appears as a fourth member in the parallel series: Hidake, Kitakami, Abukuma.

The Bonin ridge with the Fuji zone indicates, indeed, that from here toward the east lay a continent which differed from the western with its equatorial arrangement by possessing a meridional structure; and the conclusion is near that it is this once more highly projecting structure on whose western border the Japanese portion of the Tsinling range has been dragged by its southwardly directed mass migration. A glance at China has shown that there chain after chain among the parallel members of this body has suffered an arc-like dragging off from north to south. The behavior here considered is analogous; it appears, as though on the site of Naumann's *Fossa magna* the last still persistently remaining member of the great trunk range suffered the same fate and at the same time tore away with it the Akaischi portion of the Kuma Kii range, while it nearly detached it

from its earlier connection and placed it in a nearly perpendicular position.

7. *Development of the Japanese Arc.* It is clear that the projecting portions of Japan do not correspond to the recognized characters of compressed mountain ranges of the Alpine type. South Japan shows in the front an arc concave toward that portion of the earth space lying in front; we could compare it to a portion of the continent taken from the Tsinling range and its adjoining ranges to the south. North Japan and Yezo on the other hand appear as fragments of an ancient continent of quite a different kind, placed transverse to the equatorial ranges of South Japan. If one considers the two parts of the continent of which the fragments are visible, not yet intersected by volcanoes but reproduced in full extent, scarcely any portion of the coast could appear less adapted for the production of the mountain arc. But exactly as upon the continent and upon the coasts, the working together of telluric forces furnished to the great fractures which they brought forth the tendency to join in great crescentic lines independent of the internal structure, and thus to develop an extended structure of the plateau block kind with sickle-like border region and with upward-arching basin-like depression toward the interior. The Japanese inland country corresponds to these conditions in its entirety, the sea of Japan corresponds with the bottom of the basin.

Like the other arcs which have been considered in these "studies," the Japanese has a meridional and an equatorial arm. The meridional arm is a diagonal horst; that is to say, its long sides (the eastern and the western, or the outer and the inner) intersect in an acute angle the internal structure. The latter is as we have seen directed N by W. The axis of North Japan, and in like manner its coast line, curves from NE, through NNE, to N; hence correspondence with the strike never obtains. It follows that the force which here produced the meridional component of the arc on the west side of the Pacific ocean, as we have learned in all other cases, was so powerful that the fault lines with it occasioned have courses without regard to any structures which were already present in its basement. Another property consists in its tendency in those places where the meridional arms join with the equatorial to form arcs, to continue again somewhat further west and form meridional arms of new arcs in flanking position. It should be here recalled that the bathymetric lines of the great deep do not go around Japan, but along the east side of the Bonin ridge in an arc which is convex to the eastward.

In the equatorial arm of the Japanese arc, the conjecture already expressed is confirmed, that for the character of these components of the arcs, the Tsinling range constitutes a partition in so far as the type of the gridiron of blocks (*Staffelroste*) arising from tensional fractures, as it occurs in Daurien and North Channel, does not appear to occur on the south side of that range. Of the Japanese equatorial limb every trace in fact is lacking. Otherwise, the lines of the Sinian system are dominant in the general plan. However, the deformations which they have suffered have influenced their courses.

The coast brings into most marked expression the bending of the range so as to be concave to the south. As in the manner of its bending, so also in the abundance of embayments, it is the opposite to that which we are accustomed to see in the folded outer ranges of mountains of Alpine type.

Of the Japanese arc, only the land which projects above the sea is shown. Whether compressed folded arcs lie in the slopes bordering the ocean or in its depth, is not to be determined. When I wrote the first parts of these "studies," I considered it as probable, and conjectured that through concentration by folding a compensation would enter for the dilatation which has come about by reason of the tension toward the east. The analytical consideration of the structure in Japan has robbed me of the conviction. There is no trace of zonally folded arcs to be discovered in the fundamental complex. In vain one seeks it in the Mesozoic deposits. Compressed folds may indeed be present in the eastward slopes toward the Tuscarora deep; but it is not probable that they surround Japan in arcs. The assumption would be better based that they accompany the Bonin ridge upon its east side.

8. *The Bandai Arc of Volcanoes* is a recent expression of the arc-forming force. From the fracture field out of which it rises in a beautiful line, there have welled up, according to Harada, in Mesozoic time rocks of many types. Along with granites, which he had inclined to ascribe in part to a late age, there were especially diorytes, quartz porphyries, and porphyrytes. A regularity in their arrangement cannot be made out. So much the more distinct is such an arrangement in the volcanoes which have been active since Tertiary time. Inclusive of Rischiri, Harada enumerated up to the Asama, 44 volcanoes, of which 8 are still active. The fracture field from which they rise may have come into existence in Mesozoic time. The formation of the connecting canals with the earth's interior along the extended continuous line, and on certain scattered laterally-lying positions, was connected with later events. There arose thus the first independent arc structure within the region of the Japanese islands. It does not follow the axis of the island arc; for if the northern portion does indeed fall in the *median line* of North Japan, it nevertheless deserts it before it reachs Asama; and if we follow its extension to the west where it is inserted in a most remarkable manner into an entirely different mountain country, almost all of South Japan lies outside the line. It soon reaches the sea. In its prolongation lies, 3° farther west, the twin pair of the circular Gòto group of islands, which are in part volcanic; yet one might venture to assume a connection.

This arc has as little foundation in the structure of Japan as have the coast lines of the north wing. It obviously depends upon the forces which formed both, but it is in contrast with them, independent by its very simplicity, and throughout a long course. In it an analogy is furnished with the Aleutian islands and with the Kuriles. Since it rests upon the ancient arc as something foreign, one may speak of its connection with it as epigenetic.

THE SUBMARINE GREAT CANYON OF THE HUDSON RIVER.

By J. W. SPENCER, Washington, D. C.

(Submitted to Eighth International Geographic Congress, New York.)
(Advance Notice.)

More than forty years ago, professor J. D. Dana first explained the channel of the continental border, extending from New York for more than a hundred miles, as the former course of the Hudson river, at a time when the continent stood higher than now (then known to be only 720 feet deep). In 1885, professor A. Lindenkohl discovered that the shallow channel became a canyon, and reached a depth of nearly 3,000 feet, but with an apparent barrier across it. Since then, both professor Dana and Dr. Upham applied this feature as evidence of continental elevation of the Glacial period. On the evidence of incomplete soundings, in 1897 I ventured to point out that the valley was traceable to a depth of 12,000 feet. Recently I have found authentic evidence, from soundings by Lt. Com. Tanner, that immediately beside the sounding responsible for the barrier hypothesis, he obtained another, which revealed a deep canyon, at this point, where the former depth had been taken on its side only. Then in the next four miles the floor drops in a step of 2,000 feet. Here another deep sounding, close upon an older and shallower one, shows a depth of 4,800 feet below sea level where the continental slope is submerged only 1,000 feet. Accordingly, there is a magnificent canyon, 3,800 feet deep, which at a little below its top is less than two miles wide. Just beyond is a tributary. This great depth is 31 miles from the head of the gorge, incising the level floor of the continental shelf, having two right-angled turns in its course. Beyond this point, the gorge is defined and extends at least 11 miles farther. At 48 miles, the right wall of more than 2,000 feet becomes less precipitous, showing that the canyon is widening into a valley with the depth of 6,200 feet below the surface at a point not in its center. I have taken the end of the more precipitous walled gorge at about six miles above this point, and the depth below the surface between 6,000 and 7,000 feet. The details of the right wall from this point onward are sufficiently full, but on

the left, the immediate position is open to some variation of location. To nearly 9,000 feet, its maximum breadth is defined, and thus we have the proof of the valley continuing to a point 71 miles from the head of the canyon, which is about 100 miles from Sandy Hook. The edge of the continental shelf is taken at a depth of 500 feet, inside of which the gorge has receded nearly 30 miles. The floor of the channel and gorge is covered with blue clay, while the level shelf is covered with sand.

I am now able to analyse this feature equally well with the canyons of the Congo and Cape Verde, or the Antillean region, with the advantage of having more knowledge of the adjacent topography and geology, so that its date can be determined as pertaining to the early Pleistocene period, and that there seems no other feasible explanation of its origin than that it was formed as a land valley when the region was 9,000 feet higher than now. For some reasons one might be inclined to reduce this amount by 2,000 feet on account of epeirogenic depression of the continental slope, but this is refuted by outside information.

The study of the shallow channels on the continental shelf, shows, after a subsidence following the period of elevation, another small elevation of 250 feet, obtained in age post-Columbia. Subsequent sinkings and minor changes are also noted.

MIOCENE BARNACLES FROM GAY HEAD, MASS., WITH NOTES ON BALANUS PROTEUS, CONRAD.

By Joseph A. Cushman, Boston, Mass.

During the last two summers two collecting trips to Gay Head, Marthas Vineyard, were made by the writer, one in July, 1903, the other in August, 1904. At both times a considerable number of specimens of the fossil crab, *Archaeoplax signifera* Stimpson, were collected, in all, several hundred specimens. Among these were a number showing the carapace almost completely. Upon examining several of these, peculiar circles were noted on the shell. The counterparts revealed the bases of barnacles, the upper parts of which were imbedded in

the matrix. In all, a number of specimens of crabs with attached barnacles were found, one crab with several, more or less crowded together. Fig 2. All the specimens were of young individuals. Figures of these are given.

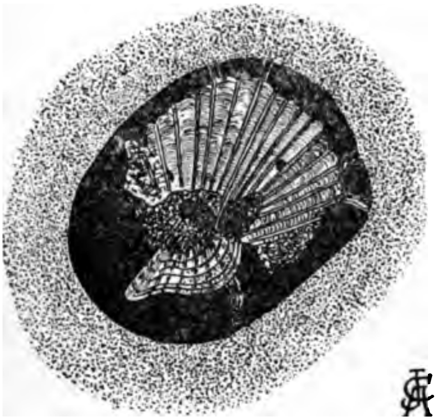

FIG. 1.

FIG. 2.

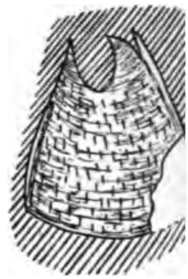

FIG. 3.

Figs. 1-3. Balanus concavus from the Miocene of Gay Head. Fig. 1. Enlarged view of basis and one opercular valve. The outer shell has been entirely lost. Fig. 2. Part of a group of young specimens upon a crab's back. Here again the shell itself has been dissolved away. Fig. 3. Cast of interior showing shape and the tendency toward plications. (Specimens in Museum of Boston Society of Natural History.)

Fragments of a Balanus were reported from Gay Head by Dr. W. H. Dall (Am. Journ. Sc., 3rd series, vol. xlviii, p. 297) as "Balanus (?proteus Conr.) fragm." Almost without exception our Miocene barnacles from the eastern United States have been referred to *Balanus proteus* Conrad. The opercular valves were not figured by Conrad, two sketches of the external view of the whole shell being all that is given in his Medial Tertiary. The original description was not accompanied by a figure.

Darwin was the first to recognize the real importance of the inner or opercular valves as a means for separating the species of Balanus. He showed that while the outer shell or testa varied with the irregularity of the surface to which it was attached, the inner opercular valves were not so affected. Darwin, in his monograph of the Fossil Balanidæ (1854,) figured for the first time the opercular valves of the common

American Balanus of the Miocene. His specimens were from Virginia and Maryland, while Conrad's type of *B. proteus* was also from Virginia. Darwin finds that the opercular valves agree in their details with those of *B. concavus* Bronn which was described in 1831, several years before the first appearance of the description of *B. proteus* Conrad. The very small use that can be made of the exterior shell is shown by the comparisons made by the two writers. Conrad speaks of his species as being close to the English *B. crassus*. A comparison of the opercular valves of his species with *B. crassus* would have shown at once the great dissimilarity of the two, although in many ways similar in external form. In the outer shell also one has the radii perforate, the other imperforate.

In his remarks toward the end of his monograph of the Cirripedia, Darwin speaks of *B. proteus* as follows, "I cannot recognize this species; it resembles *B. porcatus*; but as the radii are rather narrow, and apparently with rather oblique summits, it may be *B. concavus*; the opercular valves are not figured." Here again, the likeness to *B. porcatus* would at once have been seen to be entirely superficial if the opercular valves of the two could have been compared.

A considerable number of specimens from Virginia and Maryland, labelled *B. proteus* and corresponding in all points with Conrad's figures have been examined by the writer. Without exception the opercular valves were like those of *B. concavus* as figured by Darwin. Not only this, but in the series obtained, the very slight differences noted by Darwin were bridged over by the specimens, many of them being more like the figures of specimens from the English Crag than those figured from Maryland. Darwin, however, notes the variability of the Maryland specimens.

The specimens obtained at Gay Head are like *B. concavus* in having the basis and parieties permeated by pores. The opercular valves where shown were similar to those of *B. concavus*, Fig 1, especially to those of young specimens. It should undoubtedly be recorded as this species. Its occurrence on the backs of crabs is also in favor of its being placed under that species, which in its recent members is almost always found attached either to the backs of crabs or to shells.

In New Jersey the fragments of Balanus have been referred to *B. proteus* Conrad by Prof, R. P. Whitfield. These should undoubtedly be called *B. concavus* Bronn. In Whitfield's paper, Mollusca and Crustacea of the Miocene of New Jersey, (Monograph xxiv, U. S. G. S.), there is one thing to which attention may be called. On p. 141 he says, "No entire individual of this species has been obtained from the New Jersey deposits, so far as I am aware; but numerous separated plates are in the collection at Rutgers College." These specimens, which were from near Shiloh, N. J., are figured, Pl. xxiv, figs. 18-23. In plate iv, fig. 8, on the ear at the left of the shell of *Vola humphreysi* Conrad, there is figured attached an entire specimen of Balanus. This shell was also from near Shiloh, N. J. This illustrates the ease with which barnacles and other attached forms may be overlooked.

Although there are minor differences in the shell due to attachment, there are, nevertheless, certain variations in this species not due to this entirely. Darwin figures both smooth and plicated specimens of *B. concavus*. In American specimens there is the same variation. On a single valve of *Pecten eburneus* both forms were found. Several had four or more prominent radial plications on each of the parieties, another form of which there were several were perfectly smooth except for the lines of growth which were slightly raised. Such differences at first glance would seem to give definite varietal distinction but in a considerable amount of material it has been impossible to carry this difference beyond the early growth, both forms becoming roughened and rugose in further growth. In both forms there seems to be no appreciable or constant difference in the opercular valves. The Gay Head specimens were of the smooth type.

From the preceding it seems that we should adopt the earlier name of *Balanus concavus* Bronn for the common species of barnacle found in the Miocene from Gay Head southward through New Jersey, Maryland, Virginia, etc., instead of the commonly used name *B. proteus* Conrad.

Boston Society of Natural History, 1904.

THE THEORY OF COPPER DEPOSITION.

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During the past few years there has been a lively interest in the theory of the origin of ore deposits, and recently two works have been published by the Institute of Mining Engineers and by the *Engineering and Mining Journal,* which give a very good account of the present state of the controversy, and references enough to carry one pretty well over the whole field of the latter.† In these discussions our deposits of iron ore and copper of lake Superior have been frequently used as illustrations of the various theories by those who take part in the discussion. In view of these facts, it seems proper to give a review of what is known concerning the copper of lake Superior and of the theories regarding the same. There is also a practical interest involved in the discussion. As we shall shortly see, all the best authorities at present agree that the copper has been deposited by water, but there is some difference of opinion as to whether the water current is a descending one and copper was deposited and a circulation produced by gravity, or ascending, and the circulation due to one or more principal causes, which we may call as a common name, volcanic, meaning thereby that they are connected with the interior heat of the earth. Now, it is a common notion among the practical Cornish miners of the copper country, although I do not remember to have seen the statement in print, that the copper is liable to occur under high ground.

To understand what is meant by the expression "high ground," we must remember that at the present day the bulk of the copper is deposited in bedded lodes. It would be perhaps more correct to say that it comes from lodes whose strike

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* Advance sheets from the Annual Report for 1903, reprinted from *The Michigan Miner*, January and February, 1904. It should be understood that the title in a general magazine like the AMERICAN GEOLOGIST is too broad, for the article has reference solely to the deposits of Keweenaw Point, and the author does not wish to apply either facts or conclusions to other deposits, such as the sulphides, whose history he believes to be different.

† Genesis of ore deposits, Reprinted papers from Volumes xxiii, xxiv, xxx and xxxi of the Transactions of the American Institute of Mining Engineers. Published by the Institute at the office of the Secretary, New York City, 1902.
Ore Deposits, a discussion republished from the *Engineering and Mining Journal*, New York City, 1903.
See also *Geological Survey of Michigan*, vol. i, Part II, p. 43. Vol. vi, Part I, p. 216.
Yet more recent: Trans. Am. Inst. Min. Eng., Oct., 1902. "Igneous Rocks and Circulating Waters as Factors in Ore Deposition," by J. F. KEMP; "Ore Deposits Near Igneous Contacts," by W. H. WEED, and discussion of same. Annual report of the State Geologist (of New Jersey), 1902. "Copper Deposits of New Jersey," by WALTER HARVEY WEED. "The Chemistry of Ore Deposition," by WALTER P. JENNEY.

is the same as that of the beds of the Keweenaw formation. It is commonly accumulated in the originally more porous parts of the beds. Sometimes these porous parts are sandstones and conglomerates, but more often they are porous upper parts of lava flows. It is, I believe, true that in many cases there are faults parallel to the bedding planes, or so nearly so that the difference has not been detected, which have had an important influence on the production of copper. In some cases we know there are such faults, which generally have a somewhat steeper dip than that of dips generally.*

Nevertheless, in a practical way the most characteristic feature of these lodes is the porous beds. Any one of these porous beds may contain copper and there are few of them, which are decomposed, that do not show some trace of copper. But the parts which are relatively rich, rich enough to be the sole object of interest to the miner, are rare, and the meaning of the idea that copper occurs along high ground is, as I understand it, that in following the outcrop of such lode, chutes of copper are liable to occur where the outcrop of the lode is extra high. Now there is some ground for this idea. If we take the Baltic lode, just developed, we find that in the Baltic, Trimountain and Champion mines this is rich, while just northeast, on section 16† the Atlantic mine has done a good deal of exploring without being able to find the lode. Rising once more on the high land we find the Isle Royale mine close to the deep trough of Portage lake, where, on the other side, is the Quincy mine, on high land again. The Sheldon and Columbia and Hancock mines, more down in the Portage Lake valley, do not appear to have been so successful. Going farther north, we find the Calumet & Hecla, Tamarack, Kearsarge and Wolverine mines, not very far from the Allouez gap on the southwestern side; on the northeastern side is the Mohawk mine. Nearer the gap is the Ahmeek property, which

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* The top of the Calumet and Hecla is markedly slickensided. See also Volume vi Part II, pp. 86-94; the slide fault in the Central mine appears to be nearly parallel to the Kearsarge conglomerate. The accumulation of copper was in the vein above this slide, and on reaching the conglomerate they worked on top of it finding good copper ground.

The annual report of the Phoenix mine for 1901 shows in the section by DUNBAR D. SCOTT, the steeper fault slide in that mine, in the St. Clair vein. The old Minnesota, now Michigan mine, had its largest deposit of copper where a steeper fissure intersected a lode. See the report of the Commissioner of Mineral Statistics for 1880, p. 76. Copper Handbook, 1902, p. 195.

† Volume vi, Part II, Plate 10.

is just being opened up and whose true value has not been determined. If the "high ground" notion has any substantial basis, its prospects would not be so good as those of the Mohawk and Wolverine mines, although it lies on the same lode and between them. The Phoenix mine and the Cliff lie on higher land, not far from the gap of Eagle river, and turning to the other end of the range we find the Minnesota and the National on one side and the Victoria on the other of the gap made by the Ontonagon river, while the Mass and Adventure lie on the high land between the Flint and the Fire Steel rivers.

Now, this grouping of mines in accordance with this notion that the copper occurs on the high ground may be due to the fact that the porous beds are usually eroded, and therefore not exposed, and not easily exploited or developed, except on high ground. It might also be suggested that the alterations which produce the copper had cemented these beds more firmly and had thus given a greater resistance to erosion, either by ice or by water. The copper itself, however, even in the richest mines, is only a small fraction of the rock, and is easily decomposed chemically, and so are some of the associated minerals, and, although at times, copper bearing amygdaloids, as the igneous porous beds are called, are more or less saturated with silica and epidote, I do not think those minerals are so characteristic of the copper-bearing lodes as to lead to a relatively greater elevation of such parts of the lode. However, there is room here for inquiry.

I leave to the last another possible explanation which has a more direct connection with the theory of the deposits of the copper. If the copper is deposited by descending waters, as Pumpelly, who has done by far the most work upon the subject, suggested, and the motion of these descending waters is determined by gravity, descending along the lodes at one branch of the inverted siphon and rising either in the same lode at a lower point of its outcrop, or in some cross fissure, which might very well be the cause of the gap in the range, then we can readily see that the greatest activity and circulation and greatest deposition of the copper consequently, should be beneath salient points of the outcrop of the lode. Take for instance, the Calumet & Hecla. That deposit outcrops 600 or

700 feet above Lake Superior, and the chute of the richer streaks in the deposit is northward, and we may imagine the waters working down in that direction to re-appear over in the Allouez gap or up some fissure which may possibly have determined the gap. We see, therefore, that the question as to whether the copper was deposited by waters circulating in one fashion or another has a practical interest in guiding the search for the richest parts of the lode. Moreover, Van Hise has suggested that the richer parts of the lode—called chutes—will be found beneath upward bends if the waters of deposition are ascending, beneath downward bends if the waters of deposition are descending. If he is right, which I doubt, in saying that the copper of the Michigan lodes are deposited by ascending waters, the southern end of the Ahmeek and the northern part of the Kearsarge properties should be extra productive according to Hubbard's map of the Allouez gap area (Volume VI., Part II., Plate VII.), but if the waters are descending, the same area should be lean.

In the first place we may premise that it is a settled question that the copper was deposited by water. All kinds of authority agree in this, although at one time a few geologists thought of its being inserted in a molten state. But native copper and native silver occur together, as they could not if they were melted. They would at once be alloyed. Jewelry is often made of sections of nuggets of copper and silver, popularly known as halfbreeds, where the sharp and irregular line between the copper and silver is beautifully displayed. We also find copper grown upon minerals, like analcite and prehnite, which one can fuse in a candle flame. It is not very rare to find a sharp crystal of dog-tooth spar entirely plated over with copper, and then the growth taken up again.* Pumpelly has given in Volume I. of our reports a most thorough discussion of the way in which the copper occurs. A very interesting specimen, owned by Dr. Hubbard, shows a crystal of quartz which has been corroded and mainly by native copper. Moreover, in the deeper part of the Quincey mines, Dr. Koenig has found a water which is now depositing copper and contains 9 grams to the metric ton of the same.

* See Volume i, Part II, Chapter III; also Volume vi, Part II, pp. 163 to 165 of our reports.

I have shown in my United States Geological Survey water supply paper No. 31, on the different waters of Lower Michigan, that while each porous bed varies in its character of water from point to point, yet there is little intercommunication between them and it is difficult to see how there could be much, except upward along fissures or drill holes. Beds of clay or shale are known to be so impervious to water and to oil, they may be taken to be, even in a geological sense, impervious layers, permanently guiding and separating the different flows of water. The same statement applies to clayey belts of decomposed rock, paint rock and fluccan, as Van Hise himself has ably pointed out in discussing chutes and the formation of the Galena lead deposits. Thus, it must be remembered, that Van Hise's figures of underground flow apply only to a homogeneous medium. His figure 5, for instance, might represent the flow of water in one single porous bed, say of conglomerate, sandstone, or amygdaloid, but not the formation at random. It is by no means practically true, therefore, that the zone of fracture "will be searched to its base by moving waters," unless first it is not only potentially but really fractured, so as to make it practically porous as a whole, and unless, also, it is covered by a surface topography so rough as to stimulate circulation. These two conditions will be best fulfilled in those mountainous districts, which as Van Hise remarks, are most liable to contain ore deposits, page 416.

Now, the difficulty in supposing that the copper deposits are due to such a general circulation of water taken in at the surface, as Van Hise imagines are very great. The following is a sample of water from the Arcadian shaft, a relatively shallow shaft, analyzed by Dr. Koenig, August 23, 1898:

$CaCO_3$	32.7
Fe_2O_3	13.7
Kaolin	100.0
$FeCO_3$	24.5
$MgCO_3$	25.6
K_2CO_3	10.9
Na_2SiO_3	101.3
NaCl	tr.
$Na_3P_2O_5$	2.2
Na_2CO_3	42.3
Organic matter	82.0
Total	435.2

While a deep mine water coming in at the 46th level of the Quincy, analyzed by Dr. Koenig, was as follows:

Sp. Gr.	1.1898
$CaCl_2$	17.91
NaCl	2.96
$MgCl_2$	——
SO_3	0
Iron	0.004
Copper	0.009
CO_2	0.00

Now these two analyses are typical.

The deep waters are strong solutions of earthy chlorides. A water with nearly 1 per cent. of bromine oozes in the 45th level of the Tamarack. The shallow waters are high in alkalies, and so low in chlorine that the alkalies have to be combined with other acids. It is no wonder that alkaline zeolites occur in the upper levels. One might explain the loss of carbonates if the upper water was descending by a precipitation of the same such as we know has taken place, but I do not see that we can so explain the presence and absence of chlorine. That must, it seems to me, have been an original constituent of the deeper rock moisture, either of the sea in which the rocks were laid down, or of the igneous magna. Prof. Moore in his presidential address before the Liverpool Geological Society (1903, p. 269) has shown that at the top of a 96 foot thick intrusive sheet there is a 10 to 15 foot belt, corresponding to the amygdaloids of the Keweenawan series, which contains a little over 4 per cent. carbonic oxide and 2.6 per cent. water which are, as he believes, probably primary. Analysis of the Lighthouse Point dyke, which is probably one of the Keweenaw flow feeders, shows chlorine, more than enough to go with P_2O_5 for apatite, and the apatite which has been so commonly observed (Vol. VI, Part 1) also contains chlorine.

Note the apparent concentration of the early formed olivine at the margin.

Moreover around volcanic centers the escape of vapors containing chlorine and carbonic oxide and the formation of crusts of iron chloride are common.

Pumpelly furthermore concludes that the water which deposited the copper was descending. One of the arguments which he used is that the alkaline silicates abound in the upper

ANALYSES OF STONE FROM LIGHTHOUSE POINT MARQUETTE.

			June 30, 1903.	
SiO_2	46.98	47.67	57.25	47.10
Al_2O_3	17.85	17.55	18.10	17.47
Fe_2O_3	3.13	2.51	2.21	2.66
FeO	10.30	12.69	12.42	12.93
MgO	7.10	5.65	6.35	6.88
CaO	8.47	10.75	11.45	10.27
Sodium Oxide	2.04	2.21	1.98	1.91
Potassium Oxide	.60	.65	.66	.59
H_2O at about 800° C	1.97	.35		
H_2O at 110° C	1.55	·40		
CO_2	.20	.18		
P_2O_5	.143	.169	.158	.161
S	.097	.183	.086	.111
Cl	.07	.05	.02	.09
MnO	.26	.19	.18	.15
	101.880	102.422	100.744	109.522
Distance from margin	Margin	616m	4115m	Center 7600m

E. E. WARE under direction of E. D. CAMPBELL.

levels and are (page 40) rare in depth; "in other words they are abundant in that zone of the veins which lies between walls of those portions of the beds of the melaphyre in which we should look for the most advanced stages of alteration in the components of melaphyre supposing such alteration to be due to the action of descending solution." By alkaline silicates he means analcite, apophyllite, orthoclase (and datolite is of the same age). Copper occurs of similar age in some of these deposits. In studying the alteration of the lava flows which form so large a proportion of the Keweenawan series, I find that the olivine is first to alter, then the augite, and lastly the feldspar.

There are other arguments which may be used to support Pumpelly's theory with regard to the origin of copper. As has been said, down to say 500 or 600 feet the water of the mine is quite fresh. In the deeper mines while there is very little water it is an extremely strong solution of chlorides. The line between the two classes of water is reported to be very sharp, and there is a chance for a very interesting investigation right here. It would seem quite difficult to suppose a circulation of this heavy water up into a light fresh water, especially under high ground, and to imagine that there could

be a sharp line between them. One would expect to find brackish waters clear to the surface, and that even if the heavy waters rising were diluted by affluents, they would retain the same general character, whereas the surface waters and the deep waters are chemically entirely different. If there was a tendency for the waters to descend, however, the rocks might naturally draw in fresh water of entirely different character from the outcrop.

A

Figure illustrating original cavities in a rock of the copper bearing series such as may have been originally filled with chlorine gases, as at "A" wedged in between feldspar belts and an octagonal augite grain.

Van Hise might however suggest that the present distribution of waters is a recent phenomenon, the present circulation being indeed downward, but much later than the origin of the copper.

Now if vapors escape they must be present in proportion to their vapor pressure in the lava and can hardly wholly escape but must be present more or less in the rock moisture of the acid interstices which I have so fully described for the intrusive rocks. But even in an effusive as the rock (above figure) we see that between the crystal of augite and that of feldspar, each having its own shape, is an angular space which must have been originally a pore filled only with gas probably.

In a thoroughly crystalized trap, doleritic melaphyre or diabase the porosity is not over 1 per cent. But in the case of an amygdaloid the amount of vesicular space may have been very considerable, and this space must have been filled either with the original gases or possibly in the case of submarine flows with sea water more or less contaminated with such gases. Such an origin would readily account for the saline character of the waters, and it is worth noting that such saline waters attack copper as is shown by the fixtures around the salt baths of Lower Michigan.

Another most weighty argument is the occurrence of copper native in the iron ores near Crystal Falls.* One can hardly imagine this other than produced by descending waters since the iron ore is universally allowed to have been formed by descending waters. Moreover it occurs in the upper parts of iron ore bodies and is not known to have any connection with lower deposits. It may easily be conceived to have been derived from an over-lying extension of the Keeweenawan, now eroded away.

Pumpelly supposed that the copper may have been originally deposited with the strata, as sulphurets under submarine conditions. He was slightly inclined to call the old lavas altered (metamorphic) sediments.

Irving apparently agreed with Pumpelly speaking of the copper having been arrested in its descent. The more recent writers on ore deposits however seem inclined to refer the origin of the copper deposits to the upward rising waters. For instance Posepny writes as follows:

"Some of the attempted explanations assume, in my opinion correctly, as the cause of the first ore depositions, the action of hot springs—in which connection it is only to be emphasized these thermal effects occurred long after the intrusion of the eruptive flows between the sedimentary strata, so the ores were brought, not by or in the eruptives themselves, but by the later springs, from great depths and perhaps from considerable distances. This explanation, applicable to all deposits, suits also the exceptional case cited by R. D. Irving, namely, the None-

* A. E. SEAMAN writes that he has native copper in iron ores from the Cliffs mine at Iron Mountain, also with ferruginous chert from the tenth level of the Great Western mine, Crystal Falls, also from the Montana mine, Tower, Minn., where it occurs in the iron ore.

such copper bed in the sandstone of Porcupine mountain, far from an eruptive outflow." Posepny seems to have been influenced in the first place by a strong prepossession as to the role of ascending solutions, and in the second place by the occurrence of the ore as a mineral or rarely sulfide and not as carbonate.

Prof. Van Hise in his very interesting article on "Some Principles Controlling the Deposition of Ores," uses the metallic copper deposits as a conspicuous illustration of ore deposits where the concentration by ascending waters has been sufficient without secondary concentration by descending waters, writing as follows:

"In some cases the deposits thus produced are sufficiently rich, so that they are of economic importance. In these cases, which undoubtedly exist, but which perhaps are less numerous than one might at first think, a concentration of ascending waters has been sufficient.

"A conspicuous illustration of ore deposits of this class which may be mentioned are the metallic copper deposits of the lake Superior region. The copper was in all probability reduced and precipitated directly as metallic copper from upward moving cupriferous solutions. The reducing agents were the ferrous compounds in the solid form, in part as magnetite and as solutions derived from the iron bearing silicate. When the copper was precipitated, the iron was changed into the ferric condition. It is well known that metallic copper once formed is but slowly affected by the oxidizing action. Oxidation has, in fact, occurred in the lake Superior region, but from the facts now to be observed, not to an important extent. An oxidized belt may have formed in pre-Glacial times, but if so, it was swept away by glacial erosion, and sufficient time has not yet elapsed to form another. The ore deposits now worked have apparently remained practically unchanged since the time of their concentration. In this fact we have the explanation of the great richness of these deposits to extraordinary depths."

Prof. H. L. Smyth, of Harvard, has also adopted the same belief and I have already discussed it in Vol. VI. of our reports. Prof. Smyth believes that the various flows were surface weathered and the earlier non-alkaline minerals pro-

duced thereby. The later alkaline minerals he believes to have been associated with the northerly and northwesternly tilting, and the formation and the filling of the fissures and the impregnation and partial replacement of amygdaloids and conglomerates with copper, the copper not being derived from overlying sandstones nor from traps, but probably by ascending solutions from deep-seated sources.

Returning once more to Prof. Van Hise's paper, we find that however his theories may apply to other deposits, they apply very largely to copper-bearing rocks. His first premise is that the greater number of ore deposits are the result of work of underground water. His second is that the material of ore deposits is derived from rocks within the zone of fracture. This would seem to be true, and shall give some arguments for believing that the copper is derived from the associated igneous rocks. His third premise is that by far the major part of the depositing water is meteoric. By this he means that it is derived from the air, rain water which was worked down into the ground. In view of the composition of the water at considerable depths above given on the Keweenawan range, it seems probable that this is not true, but that the largest part of the water may either have been buried originally with the sediments (possibly he would class this as meteoric), or occluded in the original magna, as he suggests. It is a subject for further investigation, just how much of these three classes of water we have involved.

His fourth premise is that the flowage of the underground water is caused chiefly by gravitative stress. If this is true, and I believe it is, then it follows, as Van Hise himself has remarked (p. 417), that if the copper is most concentrated along the higher parts of the outcrop it must be formed by descending waters; moreover, as he also calls attention (p 412) in case of the minor flexures and pitching folds in the bed, if the waters are descending the richest parts should be in the troughs of these folds, or possibly on lines leading from an anticline down to the trough of the folds. Referring once more to plate 10, of Vol. VI., Part II., it will be seen that in such a case the copper of the Baltic and Trimountain may be expected to chute to the north when followed down. So should the mines around Calumet, while the Quincy mine should

chute southwestward. And yet, as the flowage of water is under gravitative stress, it must be remembered that it will take a considerable difference in head for a fresh water to move or balance water with a specific gravity of (1.1898) a fifth more. However, the Keweenawan series consists mainly of a great series of lava flows, many of them over 100 feet thick. (See as an illustration of this, the section of Tamarack shaft No. 5, and correlated beds elsewhere given.) They are not likely to have lost heat for a long time after their effusion, in fact very likely not before their burial under succeeding flows* so that for thousands of years the remnant heat of the effusions and the heat of the later intrusions may have aided the circulation, and particularly the solvent action of the water, as Van Hise (pp. 300, 346, 774), but more particularly J. F. Kemp and others have insisted. And yet the accumulation of copper in the Nonesuch belt of sandy shales, made up of lava and sand, would indicate that it is the chemical character of the lavas rather than their heat which is of most importance. The source of the copper Pumpelly considers to be sulphides originally deposited and bleached out and reduced by the ferrous iron. This may be so, and yet it is strange that we see so little of sulphides in the original rock or of sulphates in the secondary minerals. I have seen some fine selenite from the

* In the succession of flows noted in the Isle Royale drill cores of Vol. VI and the Tamarack shaft, and other sections studied if there had been a long interval between the flows and they had been exposed to air, the amygdaloids would have decayed to red clays and iron ores, and if they had been long enough under water there would have been more or less deposition. As is obvious from the Tamarack section, there is but very little deposition, and while there may have been some contemporary decomposition of the amygdaloids—in fact probably has been, and it may have helped in the copper concentration, yet in very many cases, it is clear that it did not progress far before the next flow came. In fact in some cases an effect on the marginal grain of the underlying flow is indicated. Now, for illustration's sake, if (p. 245 of the Isle Royale report, Fouque and Levy's observations) an ophite cooling in about six days has augite grains 0.03 square millimeters in area, then one which has them about 50 square mm. in area, like the Greenstone 120 feet from the wall, would take about (6x5÷ .03) 10,000 days before it had actually consolidated, that is, it would be between twenty and thirty years before the center of a sheet 240 feet thick had fully consolidated, and it would still be red hot. But the increase of the grain of the augite clean to the center shows that it must have been during a very early stage of cooling, and at a glance at Plate IV, of the same report shows that after more than ten times that lapse of time say, 200 to 300 years, the temperature at the center would still retain something like an eighth of its original excess of temperature over the country rock. The temperature toward the margin decreases, of course and the total amount of calorics yet left in the flow will be readily found by integrating equation (11) or (12) of the Isle Royale report. Of course the above figures make no pretense to accuracy. We have no right to apply Fouque and Levy's observations on the grain of a rock of one composition off hand to another. Yet the order of figures is likely to be the same, and it is plain that if the Tamarack cross section has some fifty flows, and this section only represents a third or less of the whole pile of flows thus rapidly piled on each other there may have been temperatures near boiling ten thousands of years after the formation of the pile, during all of which time the zeolites we now see may have been forming. Obviously, too, there will be a large amount of energy to promote aqueous circulation.

National mine, but in general sulphates are rare. The arsenides and sulphides that do occur are very peculiar, occurring mainly in the veins, and perhaps rather more frequently as at mount Bohemia, associated with the acid rocks. There are signs that at least at times they are secondary after the native copper. It has occurred to me that possibly a ferrous or ferric chloride containing a trace of copper was an early volcanic emanantion. It is, however, also true that olivine, which is one of the earliest minerals to develop, contains ferrous silicate with which is likely to be associated a trace of copper and nickel. Furthermore, under the microscope the olivine, an early formed mineral, appears to gather at the sides of this dike and the top of the flow. Analyses (Vol. VI. and here) seem to indicate the same thing in the variation of the magnesia and iron.

Thus the copper may have been concentrated. First, with the olivine of the amygdaloid traps; secondly, by leaching out of the olivine which decomposed either by atmospheric action and meteoric waters, or immediately after the outflow of the lava in the presence of the waters, acid and perhaps hot, buried with this formation; thirdly, by reactions due to the circulation downward of this water set up by this uplifting of the edge of the great lake Superior synclinal. It must also be remembered that according to the earlier geologists there has been enormous erosion, which, according to L. L. Hubbard's theory (V I., p. 94), may be in part replaced by a sliding of the upper beds on the lower for miles. In either case there may have been a considerable migration downward, in the porous belts of the formation, of the material of the strata and the original water thereof.

There is yet much to be learned, but three things appear to me to be extremely probable; the copper was associated with the original lava flows; that originally deposited water or gas has been an important factor, possibly merely in bringing copper into solution, and that the water circulation which finally precipitated the copper was downward.

It is apparent, however, that we need to test the rival theories. We need to trace some one horizon some one conglomerate or flow continuously through and survey it carefully and accurately to determine the minor flexures. Dr. L. L. Hubbard has done this in part, but the work is not complete.

THE UNTENABLENESS OF THE NEBULAR THEORY.

II.

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THE RECIPROCAL INFLUENCE OF THE HEAVENLY BODIES AND THE INCLINATION OF THE PLANETS' ORBITS TO THE ECLIPTIC.

§9. We have already mentioned, in an article in the last issue of the AMERICAN GEOLOGIST, that it was the relative positions which the Sun, the planets and the moons occupy towards one another, that in the opinion of Laplace seemed to point to such an origin of these bodies as is presented in the nebular theory. It is proper, therefore, that we now try to ascribe this state of things to other causes.

Since it is the attraction of the Sun which causes the planets to revolve in their orbits around the Sun, and likewise the attraction of the planets which causes the moons to revolve around the planets, it is plain, also, that it is the same influence which determines, at least in the main part, the relations of the planetary orbits to one another and to the Sun, and also the relation of the orbits of the moons to one another and to the planets.

The question, then, is simply this: In what manner have these relations been established.

We cannot speak of gravity as the motive force which causes the motions of the planets and by virtue of which the velocity of the Earth, for example, is 72 times that of a cannon ball without at the same time supposing that there must be a constant tendency, especially between the larger planets—Jupiter and Saturn—and the Sun, to draw the inner planets, at the time of conjunctions, in a straight line toward the Sun. This cannot be denied, since attraction acts reciprocally. The case is similar to the one when we as boys used to pull *tug of war*, which was a reciprocal attraction, and the result of which was a straight line. This point may be better illustrated, however, by supposing a steamship of about 10,000 tons carrying capacity, or somewhat larger, as

representing the Sun, and this ship connected by means of a cable with another ship of about ten tons carrying capacity representing Jupiter, and that these two ships would pull with all their might in opposite directions. We suppose, further, that to the cable—representing the force of gravity—connecting the two ships were fastened small boats of from about 70 to 640 *pounds* carrying capacity. These would represent the inner larger planets. We must then certainly admit that the cable, with one ship at either end, and the ships pulling with all their power in opposite directions, would represent a straight line, if not influenced by some other force, causing a different result.

Those two ships and the small boats, may be said to be in conjunction: and such a position is sometimes occupied by all the planets simultaneously. This happens very seldom, however, but sometimes it does happen. Jupiter, Uranus and Neptune formed about a straight line with the Sun in 1881-82, whereby the inner planets in crossing this line were also placed in the same conjunction. The tension is, of course, greatest during such epochs; but Jupiter alone will, as shown in the example above, hold the orbits of the inner planets in the ecliptic or about identical with its own orbit, when they come between him and the Sun once in each anomalistic period. When we, further, notice that Neptune at a distance of 1,000 million miles exerts a disturbing influence on Uranus, which observations have convinced us of, then we may safely consider it established beyond all doubt, that the positions and relations of the planetary orbits as determined are fixed and unchangeable by the reciprocal attractions of the Sun and the planets. All this is, indeed, simple and natural. And thus we understand that we can explain these phenomena without supposing, as the cosmologists have done, the existence of a nebula with a diameter of over 5,000 million miles, in order to make it explicable.

It is equally clear, that the moons are subject to the same kind of attractions, since they frequently are in conjunction not only with the Sun, but also with each other. The inner moon of Mars, for instance, comes between the Sun and the planet three times a day. It appears plain, therefore, that

the influence of the conjunction is the sought cause of the parallelism of the moons' orbits with those of the planets.

But there are other forces at work upon different principles and leading to different results than that of attraction. One of these forces we shall point out presently. Let us first, however, notice that the peculiarity which we here come in contact with and which the cosmogonists have paid most attention to, is the analogy existing between the planetary orbits and the Sun's plane of rotation; and also the corresponding analogy between the moons' orbits and the planet's plane of rotation.

Why, we may ask, does not the Sun rotate perpendicularly to the plane of the planets' orbits, as well as in a plane identical with them? And why do not the planets rotate perpendicularly to the plane of the orbits of the moons as well as in a plane coinciding with them?

It appears at the first glance as though the planets were subject in one way or another, to the force by which the Sun rotates, and that the moons likewise have something to do with the rotation of the planets. This is the point which science so long, but unsuccessfully, has sought to explain.

In a following chapter we shall discuss the law of rotation and we shall then solve this problem, and show that these things are simple, and that they may be easily understood after we have found the key to the secret. This key we cannot find, however, until we have cleared away a number of misconceptions. It often happens, as we shall find, that what has been accepted as a result of one single cause only, is the result of several causes acting together, and it may even be the result of causes which so far have been unknown or misunderstood. In order, therefore to explain correctly any phenomenon which is a result of a combination of causes, we must distinguish each cause and every factor and explain them separately.

§10. THE CAUSE OF THE INCLINATION OF THE LUNAR ORBIT TO THE ECLIPTIC, AND OF THE PERIODICAL OSCILLATION OF THIS INCLINATION.

The inclination of the lunar orbit to the ecliptic varies, according to C. A. Young, between $4° 57'$ and $5° 19'$, the

extent of the oscillation being 22′. The maxima and minima of this oscillation, in general, are not the subject of consideration in this treatise. We propose, however, to discuss a peculiarity concerning this oscillation, which hitherto seems to have escaped the attention of astronomers. The fact is, that the oscillation of the lunar orbit is, itself, subject to a periodical variation, a variation which stands in harmony with the oscillating activity of the Sun. By demonstrating what the cause of this periodical variation is we shall also, thereby, have proven what causes the entire inclination of the lunar orbit to the ecliptic.

It seems, at first glance, quite natural that this characteristic of the oscillation which we shall presently consider is due to the Sun's light, since it appears as a result of the variation of its energy.

Let us therefore, briefly consider the light and the Sun's varying activity during a given time, and then compare the results with the oscillations of the lunar orbit during the same period.

It is a known fact, that an object facing the Sun, dams up the light. We know, further, that the solar rays fall with greater strength when they strike an object perpendicularly, than when they strike it horizontally. The result of this is the much higher temperature at the equator than at the poles. Thus we understand that as an object dams up the sunlight on the Earth's surface, in like manner does the Earth dam up the sunlight in space. The torrid zone becomes the middle line in this light-belt, which, thus, lies in the ecliptic and diminishes in density as the distance from this line increases on either side. When we remember, further, that light is electro-magnetic and as such has a tendency to make the ether active wherever it is dammed up, we can no longer fail to see that a layer of light-atoms or active ether surrounds the Earth in the ecliptic and very likely reaches a distance beyond the orbit of the moon.

This ether, thus acted upon, is different from ether in general, not only as vibrating and active, but also as offering a resisting force. It seems, then, that it is on account of this that the moon crosses this zone and inclines to the ecliptic, since the resistance met there decreases towards

higher latitudes. We shall see what the oscillation proves regarding this matter.

It is a known fact, that the active condition and eruptions of the Sun are varying. Now, since the radiation of light is of a certain periodicity and oscillates between maximum and minimum, it follows that for the same reason the light-stuff around the Earth is of oscillating density; and the moon in consequence, meets with an oscillating resisting force. It is remarkable, indeed, to notice that the oscillation of the lunar orbit stands in very close relation to the oscillation of this resisting force, and in a degree which seems to answer perfectly to the richness of the light-stuff which causes the resistance. By comparing the varying inclination of the lunar orbit to the ecliptic, as it is indicated in the ephemerides, with several succeeding maxima and minima of the Sun's varying activity during the same period, we come in possession of the necessary data, which throw light on this subject.

The Sun's activity was at maximum, for instance, in and about 1870; we may count it a period of three years. The following minimum occurred in and about 1876. The next maximum rose high in 1880, but covered at that time a longer period than in the 70's. Eruptions of the Sun to the hight of from 100,000 to 400,000 kilometers were observed during this maximum for several years. The following minimum occurred in 1887; but this minimum did not fall as low as the foregoing one, which is generally the case with a minimum following a high maximum. Thereupon a maximum again began to appear, which reached its culmination in 1892. This is well known to astronomers, and not least from the extent of the Sun's corona at the time of the eclipses during that period.

Let us now compare these maxima and minima with the oscillation of the lunar orbit during the same period, and see if we can find their reciprocal relations.

The inclination of the lunar orbit to the ecliptic, which we have above indicated as varying between 4° 57′ and 5° 19′, fell during the maximum activity of the Sun in November, 1868, only to 5° 0′ 5″, as its minimum, and rose in February the following year to 5° 17′ 54″. This was the highest mini-

mum and maximum inclination during that solar maximum. In December, 1875, the minimum of the inclination fell to 4° 58′ 42″ and its maximum in March, 1876, reached only 5° 16′ 45″, which, thus, was during the minimum activity of the Sun; and this was the lowest minimum and maximum inclination during that period. The inclination during this minimum activity of the Sun was 1′ 23″ less than it was during the maximum solar activity in November, 1868.

In like manner the inclination was 1′ 19″ greater during the solar maximum in February, 1869, than it was during the minimum in 1876. In April, 1880, when the Sun's activity was close to its maximum, the minimum of the inclination fell to 5° 0′ 2″ and was, consequently, 1′ 20″ above what it was during the preceding solar minimum in December, 1875. In July, 1883, when the Sun's activity still was at its hight, the inclination of the lunar orbit fell only to 5° 0′ 7″ and rose in October of the same year to 5° 17′ 50″, which was the highest point during that solar maximum.

During the following solar minimum, the minimum inclination fell, in November, 1887, 39″ lower, and in January, 1888, its maximum was 51″ lower than during the preceding solar maximum in 1883.

It is important to notice, that as the Sun's minimum activity was higher during this epoch than in 1876-77, so the inclination of the lunar orbit also stood higher.

As the Sun's activity now began to increase, the inclination of the lunar orbit became relatively greater. Thus in April, 1889, its minimum was again the same as in July, 1883, or 5° 0′ 7″ and its maximum in December, 1890, 5″ higher than in October, 1883, or 5° 17′ 55″, but during the maximum solar activity in 1893 it reached the exceptional extreme of 5° 18′ to the ecliptic.

These data from the ephemerides have been furnished by Mr. W. T. Carrigan of the Nautical Almanac Office in Washington.

They are presented below in tabular form together with the solar maxima and minima.

This shows, conclusively, that the periodical variation in the oscillation of the lunar orbit is coincident with the oscillation of the solar activity, which, as we have shown above,

causes the dammed-up light-waves in the ecliptic around the earth to vary in harmony with its own variation and also further, to transmit the same periodicity to the oscillation of the lunar orbit.

Maximum and miminum inclination and oscillation of the lunar orbit.						Maximum and miminum solar activity during the same period.
1868	Nov.	5°	0′	5″		
1869	Feb.	5°	17′	54″	Max.	1868-'71 Max.
1875	Dec.	4°	58′	42″		
1876	Mar.	5°	16′	45″	Min.	1875-'78 Min.
1880	Apr.	5°	0′	2″		
"	Dec.	5°	17′	41″	Max.	1880-'83 Max.
1883	July	5°	0′	7″		
"	Oct.	5°	17′	50″		
1887	Nov.	4°	59′	28″		
1888	Jan.	5°	16′	59″	Min.	1887-'88 Min.
1892	Feb.	4°	59′	18″		
"	Oct.	5°	18′	0″	Max.	1890-'93 Max.

We have above called attention to the fact, that the probable cause of this periodical oscillation of the lunar orbit, would prove to be the cause of its whole inclination to the ecliptic. That this really is the case, seems to be well demonstrated by the fact that the weaker the light-force the less the inclination, and that the stronger the light-force, the greater the inclination. The reasonable conclusion follows that the light-zone around the earth is the prime cause on account of which the moon intersects the ecliptic.

The periodical oscillation of the lunar orbit, as here presented, verifies the theory of the meteorologists, which holds that cyclones are of a magneto-electric character, and are originally caused by the Sun, since they follow the rising and falling solar activity in their force and frequency.

We may add, further, that if the varition in the radiation of light causes the periodical variation in the oscillation of the lunar orbit, there can be no doubt about the manifestation of the light-force in meteorological phenomena. Hence we should find that all these oscillations are very closely related, originating from the same central force, the Sun, and having the same characteristics.

The following example of the oscillating energy of tornadoes and other severe storms may be of interest to call attention to in this connection:

Tornadoes and severe storms in the United States, reported by Professor H. A. Hazen, for 1875-1887 inclusive, and the maximum and minimum inclination of the lunar orbit during the same period.

Years	Tornadoes	Inclination of the lunar orbit				
		Apr.	5°	17′	29″	
1875	69	Dec.	4	58	42	
		Mar.	5	16	45	Min.
1876	68 Min.	June	4	59	8	
		Mar.	5	17	32	
1877	111	Nov.	4	59	35	
		Feb.	5	17	53	
1878	108	Oct.	4	59	15	
		Jan.	5	16	59	
1879	98	Apr.	4	59	5	
		Apr.	5	0	2	
1880	269	Dec.	5	17	41	
		Mar.	4	59	39	
1881	169	June	5	17	29	
		Aug.	4	59	14	
1882	266	Nov.	5	17	25	
		July	5	0	7	Max.
1883	589 Max.	Oct.	5	17	50	
		Apr.	5	17	21	
1884	462	Dec.	4	59	39	
		June	4	59	43	
1885	374	Sept.	5	17	14	
		Aug.	5	17	52	
1886	243	Nov.	4	59	44	
		Feb.	5	17	41	
1887	183 Min.	Nov.	4	59	28	Min.
		Jan.	5	16	59	

The following facts demand attention: In 1876 the inclination of the lunar orbit was at its minimum, and in like manner the storms and tornadoes were also at minimum; thereupon the inclination increased, and was followed by an increase in violent storms; then a decline in the inclination occurred in 1878-79, which was followed by a similar decline in the frequency of storms and tornadoes. Thereupon the inclination rose high the following year, 1880, and the tornadoes which in the preceding year numbered only 98, now reached the number of 269. Again there was a decline in the inclination, and again there was a simultaneous decrease in the frequency of tornadoes, and as the inclination reached its maximum in 1883, the storms and tornadoes also reached their maximum at the same time; and as the inclination again fell to its lowest minimum in 1887-88, the same epoch was also characterized by a minimum for violent storms and tornadoes.

In view of the fact that observations have recorded a corresponding and simultaneous variation in the solar activity, it is, indeed, remarkable to notice how the magnetic waves from the sun, are registered by the moon as they approach the earth and manifest themselves in atmospheric agitations.

§11. THE CAUSE OF THE LARGE INCLINATION OF THE ORBITS OF CERTAIN PLANETS TO THE ECLIPTIC.

Observations show, that the eruptions and protuberances of the sun are greatest and of more frequent occurrence in the sun's equatorial region, and that the activity of the light power, as a rule, is greatest there. From this it follows, that the light-stuff is relatively denser and more powerful in the ecliptic than towards higher latitudes on either side of it. The swiftest planets, which are nearest to the sun, consequently meet the greatest resistance in the ecliptic. Now since this resistance decreases in proportion to the rarification of the light-stuff north and south from the ecliptic, it follows naturally that these planets intersect the ecliptic and incline to it in the same manner as the moon.

For the reason, then, that the light-force is stronger in the ecliptic, and most active nearest the sun, the orbit of the planet which is nearest to the Sun and has the greatest velocity, also has the greatest inclination to the ecliptic.

Leverier, thus, found an inclination of 12° for Vulcan, a small planet between Mercury and the Sun. Mercury has an inclination of 7° and Venus 3½° from the ecliptic.

The decrease in the inclination of the orbits of these planets in proportion to the increase in the distance from the Sun, is thus a result of two causes, principally, namely, the diminution of the light-force and the decrease in the planet's velocity simultaneously with the increase of the distance. This decrease in the inclination as the distance increases, depends, further, upon the size of the planet, since a smaller planet meets a greater resistance proportionately to its mass than a larger one. Mercury would thus have had a greater inclination in the orbit of Venus than Venus itself has; and Venus would, therefore, have had a less inclined orbit at Mercury's distance from the Sun, than Mercury itself has.

This circumstance, that the resistance of the light-force is greater proportionally in relation to the power and mass of

the smaller planets than to that of the larger, appears to be the sole reason for the inclination of the orbits of the minor planets between Mars and Jupiter of from 8° to 30° to the ecliptic. The same condition is, therefore, the cause which prevents the reciprocal attraction of the Sun and the large planets from keeping the minor planets in orbits parallel to the orbits of the large planets.

In view of this, it is also evident, that Saturn's inclination of 2½° to the ecliptic is due to his large appendix of rings, on account of which he meets a much greater resistance in proportion to his mass than, for instance, Jupiter.

In conclusion a few remarks may be added as to the inclination of the orbits of the moons of other planets, as, for instance, in the case of Uranus. This question I intend to deal with separately from the one discussed above.

I will say beforehand, however, that by a thorough examination, we shall find at least two forces, aside from that of gravity, acting upon the satellites. We shall also find that one of these forces is at work most strongly in the outer region of the solar system, and affects the satellites of the remotest planets the most and determines the inclination of their orbits, while the other one, as shown above, acts strongest on both the moons and planets which are nearest to the Sun. For this reason it would be an error to assume, as some might be apt to do, that the inclination of the orbits of all the satellites to the orbits of their respective planets is, in all cases, due to one and the same cause.

(To be Continued.)

EDITORIAL COMMENT.

THE STONE REEFS OF BRAZIL.

The Stone Reefs of Brazil; Their geological and geographical relations, with a chapter on the coral reefs. JOHN C. BRANNER; pp. 285, 99 plates. Bulletin of the Museum of Comparative Zoology. vol. 44, Cambridge, 1904.

This volume is the result of labor that has been in hand for about 25 years during which Dr. Branner, in getting the information upon which his conclusions are based, has gathered probably the largest library extant on Brazilian and

other South American geology. He has repeatedly visited and reviewed portions of the field of study, and finally received the assistance of Dr. Alexander Agassiz by which he has been enabled to make a somewhat exhaustive study and final publication of one of the most far-reaching investigations. The problems involved are complex and difficult to be compassed except by long research and comparative study.

The subject of this investigation is one that is new to geological literature, and the methods of investigation had to be determined as the aspects of the problem were discovered. Hence it is entirely an original investigation. The geologists of North America may not at the outset take due notice of this work. But it will repay a careful reading. It brings to light some oceanic effects along coast lines which are either unknown or at least are obscure and unappreciated. It will add a new chapter to the dynamics of oceanic geography.

Except for minor interruptions due to local conditions and agencies these reefs are formed along the east coast of Brazil by forces that have acted from Maranhao to southern Bahia. Many of the important harbors and the towns located on them are due to the existence of the reefs. "Without these reefs there would be no Pernambuco, no Rio Grande do Norte, no Porto Seguro, no Santa Cruz, to say nothing of minor ports like Rio Formoso, Serinhaem, Tuape, Traicao, Mamanguape, and many others where the sugar boats load and take refuge along the whole coast from southern Bahia to Ceara and Maranhao."

Nearly all former observers have confounded the stone reefs with coral reefs, but the latter are more extended, running along the coast from the Abrolhos islands in south latitude 18°, nearly to the mouth of the Amazon river. These reefs, therefore, both affect that part of South America that forms the great nose or eastern projection of the coast line. Dr. Branner thus summarizes their geological and geographical peculiarities:

1. They are of sand consolidated to a hard—in places almost quartzitic—standstone.

2. They stand about flush with the water at high tide, while at low tide they are left exposed like long, low, flat-topped walls, with a width of from five meters to one hun-

dred and fifty meters, and a length of from a few paces to several kilometers.

3. They accompany the shore line with many and great interruptions, from north Ceara to Porto Seguro, a distance of 2000 kilometers.

4. With unimportant exceptions the reefs do not occur along the Brazilian coast beyond these limits.

5. They usually stand across the mouths of streams and estuaries, forming perfect natural breakwaters for the small harbors behind them. Sometimes they follow the shore, either on the beach or at a short distance from it.

6. They are all nearly straight. When crooked, their curves are gentle.

7. The structure and position of the reefs and the animal remains they contain show that they have been made by the lithification of beach sands in place.

8. When stone and coral reefs occur together, the stone reefs are inside or landward of the coral reefs. It is possible, however, that there may be buried coral reefs in some cases to the landward of some of the stone reefs.

9. The coral reefs are now growing over and upon the stone reefs in some places, while at other places there are stone reefs overlying dead coral reefs.

10. In general appearance, elevation, and position, the standstone reefs bear a striking resemblance to the coral reefs.

The cause and history of these stone reefs were found to contain the elements of a great many problems, some of them reaching back of the present and requiring a study of the geographic development of the entire coast line, a study that has never yet been attempted.

After giving a general sketch of the geology of the Brazilian coast line and a detailed description of the reefs themselves at numerous chief localities, the author enters upon an inquiry as to their cause. Their structure was found out to be that of beach sand, loose and irregularly bedded below but cemented into firm rock above, through a thickness of three or four meters, the cement being carbonate of lime. It seems plain that some cause peculiar to the Brazilian coast must be largely responsible for such persistent off-shore beaches, else they would be a more common phenomenon. In but few other

localities has Dr. Branner been able to find such reefs mentioned, viz., about the shores of Asia Minor, to some extent about Greece and about Sicily, and upon the shores of the Red sea. These bear some resemblance to the stone reefs of Brazil and have been produced by the recent hardening of beach sands by the deposition of carbonate of lime.

Consequently the investigation resolved itself into the question: Why is this hardening of beaches by lime apparently confined to the beaches of the Levant and those of the northeast coast of Brazil?

The sands were microscopically and chemically examined. They are mainly quartz, which is often abundantly supplied with inclusions. In these inclusions are sometimes two or more bubbles, and the inclusions are then believed to be of glass. From this circumstance the quartz is referred to a molten magma having a deep-seated origin and is supposed to have been derived from granite or some rock formed under similar conditions of depth and pressure. It is, however, as appears to the writer, more compatible with the granitic texture to exclude glass from deep-seated structures, and to assign it to surface volcanic rocks. Indeed the presence of glass in any rock implies sudden cooling from a molten condition and that could hardly take place except at or very near the surface. If the glass be correctly identified, it is evidence hence of surface volcanic rock as the source of the quartz containing it. Chemically the cemented sands contain over 63 per cent of silica, over 2 per cent of carbonate of lime, about 5 per cent of carbonate of magnesia and very small amounts of soda, potash, iron and alumina.

The author considers and dismisses the following partial sources of the material of the cement:

1. Dissolved from rain-water, or spray from the beach sands themselves; that is, carried from the upper layers of the sand and deposited in the lower ones.

2. Deposited from the ocean water after having been derived (through agency of carbon-dioxide) from calcareous organic bodies in the sea.

3. Brought down from the land by streams.

4. Dissolved from calcareous beach sands by fresh (or acid) water of streams entering behind them, and redeposited while passing seaward through these sands.

5. Possible influence of climate.

While all these sources of the calcareous cementation of the Brazilian beaches are admitted as contributory to the result, they do not, either singly or combined, answer the demand, because they are not exceptionally local as the beaches are, but are world-wide in their operation and would produce universal cementation of oceanic beaches.

The author finds that calcareous deposition from oceanic water is in proportion to its density. He reproduces a portion of a chart taken from the Challenger reports, (vol. i) showing the areas of densest sea waters over the globe. The Mediterranean and the Red sea are densest, and aside from those areas the east coast of Brazil and the central parts of the Atlantic ocean are represented as approaching nearer to them than any other oceanic waters. The westward moving tropical current is rendered more dense by evaporation in traversing the Atlantic from the African shores, and by the time it reaches Brazil it is ready to part with some of its mineral solutions. The latitudes in which this current impinges on South America are coincident with those of the Brazilian stone reefs. Hence the author finally concludes:

"The cementing material of the Brazilian stone reefs is chiefly lime carbonate.

The hardening of beach sands may be produced in the following ways:

1. By carbonated rain water dissolving out the lime carbonate in the upper portion of the calcareous sands and depositing it in the lower portions.

2. By the escape of carbon-dioxide from the sea water when the surf breaks upon the beaches.

3. By the escape of carbon-dioxide from sea water where where it is warmed by the tropical sun.

4. By the submarine escape of carbon-dioxide from about volcanic vents.

"These processes may have contributed somewhat to the hardening of the Brazilian reefs, but they do not seem competent to account for them altogether. These theories are especially incapable of accounting for the lithification of beaches behind older reefs."

"The distribution of the consolidated beaches of northeast Brazil leads to the inference that the consolidation is directly related to the density of the sea water."

As to the age of these beaches, they seem to be interbedded only with Pliocene and recent rocks, although they are built against rocks of all ages. It is therefore inferred that the formation of the stone reefs began in early Pliocene times, and that it has continued to the present.

It is probable, therefore, that the Brazilian coast has been extended eastward by this process of land-making and that it will continue to be extended until some geological revolution diverts or destroys the equatorial current. That branch of this current which passes northwestward becomes so diluted by the fresh waters of the Amazon that its mineral solutions are carried on and do not serve to cement the beach sands. The same change takes place, doubtless, in the waters of the southern branch of this current, by reason of the greater and freer drainage from the land in reaching the southern subtropical and temperate latitudes. In the tropics, as in the Levant, the surface waters are largely evaporated before reaching the ocean.

The volume is accompanied by numerous plates, taken from photographs reproduced in the excellent style for which the Museum of Comparative Zoology is known, and by hydrographic charts from the Brazilian surveys and original surveys by the author and his assistants. N. H. W.

REVIEW OF RECENT GEOLOGICAL LITERATURE.

The Geology of the Watkins and Elmira Quadrangles accompanied by a Geologic Map; bulletin N. Y. State Museum 81, 1904; John M. Clarke and D. Dana Luther.

The Watkins and Elmira quadrangles lie to the east of the Canandaigua-Naples sheet which has but recently been issued and the work now published has been carried out as a continuation of the former areal mapping. An interval between the two sheets is now in process of survey. As in the former work the large scale of the map has been made use of in delineating the variations in the formations with great exactitude, since experience has shown that in the terranes under investigation a reliable basis of discrimination of such refined subdivisions as the authors have arrived at can be found alone neither in geologic nor in paleontologic data.

The rocks shown upon this map all belong to the late Devonic and they have been classed in the following divisions:

Chautauquan	Chemung sandstone and shale Prattsville shale
Senecan	High Point Sandstone West Hill flags and shale Grimes sandstone Hatch shale and flags Rhinestreet black shale Parrish limestone Cashaqua shale West River shale Genundewa limestone Genesee shale

The distinction between Genesee shale and West River shale (the upper division of the Genesee shale series) which obtains further west is still maintained in this region while the Middlesex shale, a distinct stratigraphic element, at the base of the Cashaqua shale in the Naples quadrangle is no longer recognizable in the Watkins quadrangle. Both the Parrish limestone and the Rhinestreet shale have been traced as far as Seneca lake, but are not known east of that meridian.

In the Hatch shales and flags which attain a thickness of 440 feet, a distinct oscilation between the areas of the western or Naples fauna and the eastern or Ithaca fauna has been observed.

The High Point sandstone has in this quadrangle furnished calcareous lenses with their characteristic brachiopod fauna.

The Prattsburg shale, a name proposed in the explanation of the Naples sheet for the eastern extension of the Wiscoy shale in which a typical Chemung brachiopod fauna appears, is strongly developed in the Watkins quadrangle and has furnished a large fauna.

In order to arrive at the precise use of the term "Chemung" which has in late years been more or less identified with the horizon of *Spirifer disjunctus*, the authors have found it necessary to return to Hall's original employment of the name, since in this eastern region *Spirifer disjunctus* does not appear until the period of Chemung deposition is well nigh over. The region here considered is that from which the original definition of the term was derived. This typical Chemung attains in the Elmira quadrangle a thickness of 800 feet.

The aggregate thickness of the Upper Devonic formations represented on the sheet is approximately 2244 feet. There are some notable undulations of the strata which present striking northern dips.

Geology and Water Resources of Part of the Lower James River Valley, South Dakota. By J. E. TODD and C. M. HALL. U. S. Geol. Survey, Water Supply and Irrigation Paper No. 90. Pages 47, with 23 plates. 1904.

The area here described, partly from field work by the late Prof. Charles M. Hall, includes the Alexandria, Mitchell, Huron, and De

Smet quadrangles of the national topographic survey, together covering a square degree in latitude and longitude. An unevenly eroded surface of the Sioux quartzyte was enveloped by the Cretaceous series of the Dakota, Benton, Niobrara, and Pierre formations, almost level in stratification; and upon these are spread the till and modified drift, with the Gary and Antelope moraines. Artesian wells are obtained throughout nearly the entire district, as also farther north and south along the James valley, deriving their waters from various horizons in the Dakota sandstone, and from higher sand beds included in the Benton shales. The numerous maps of this report, and its very abundant drafted sections of the strata penetrated by deep wells, give a most detailed view of the rock formations and the artesian water supply.

W. U.

Glacial Waters from Oneida to Little Falls. By HERMAN L. FAIRCHILD. Report of the New York State Geologist, 1902; pages r19-r41, with 26 plates, including three folded maps. Albany, N. Y., 1904.

Elaborate field studies and maps, with photographic illustrations, of the numerous small glacial lakes and their channels of outflow in central New York, east of the great glacial lake Iroquois, are presented in this paper. The front of the continental ice-sheet receded northwestward from this upper part of the Mohawk valley, which was thus opened slowly from Little Falls to Oneida and Rome, before the water body in the basin of lake Ontario completed its fall from the level of lake Warren to that of lake Iroquois, a vertical fall of about 440 feet.

Three stages in the Late Glacial and Postglacial history of the upper Mohawk valley are recognized by Prof. Fairchild, who summarizes them as follows:

"1. The Pre-Iroquois or Glaciomohawk waters. These were held in the valley during the ice retreat. They would have been lacustrine except for the detrital filling, but were probably fluviatile in the section below Utica.

"2. The Iromohawk river. This great river, draining lake Iroquois and the area of the Great lakes, was the predecessor of the St. Lawrence and was the equal of that river in size and possibly in length of life. For some thousands of years it swept the valley, trenching the rock barrier at Little Falls and grading its channel to that falling base level. . . . . .

"3. The Mohawk river, the shrunken successor of the Iroquois flood.

"It would be interesting if we could apportion with some certainty the work of the three stages. It seems likely that the work of the last stage, the present river, has been comparatively small. The diminished river has cut only about 20 feet into the channel which it found, and is meandering in a discouraged and listless way over the broad plain of its gigantic ancestor. It is unable to lower greatly for itself the rock barrier. But between the effects of the first two stages the decision is not so clear. The Glaciomohawk waters were large in vol-

ume and long in life, with great erosive power. Perhaps they not only denuded the Archean rocks at Little Falls, but cut these down to the terraces under 500 feet. Then the Iromohawk used the remaining drift in the valley as an abrasive to rasp down the rock barrier to near its present condition, cutting away the valley deposits of the earlier stage and grading its channel to the falling outlet."

The time occupied in the retreat of the ice-sheet from the south to the north side of the Adirondack mountains, until it permitted lake Iroquois to be drawn down below its Rome outlet, seems to the reviewer to have been probably shorter than it is estimated by the author; for the whole duration of lake Agassiz, the largest of our glacial lakes and far the longest from south to north, appears to have been no more than about one thousand years.

Furthermore, the time required for the erosion of the gorge below Niagara falls, comprising both the Iromohawk stage and the Postglacial stage of the present Mohawk river, is shown by the investigations of Wright and the present reviewer to have been probably no more than 10,000 or even 7,000 years; as likewise the age of the gorge below St. Anthony falls on the Mississippi, from Fort Snelling to Minneapolis, eroded during practically the same period as the Niagara gorge, is estimated by Winchell to have been about 8,000 years. In that period, the part belonging to the Iromohawk river, that is, to the life of the glacial lake Iroquois, could be only a quarter or a fifth, or less, leaving much the greater part of the period as the time since the front of the ice-sheet retreated beyond our northern international boundary. W. U.

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CORRESPONDENCE.

PALAEONTOLOGIA UNIVERSALIS.—The writer desires to call the attention of American geologists to the fact that this very important work has but 21 subscribers in the United States, while France has 63 and Germany 96. Certainly the geologists and geological libraries of this country are not yet supplied with this publication. Fasciculi I and II have been issued; these contain 97 sheets redescribing and refiguring 46 of the old and little known species. It is intended to issue annually from 150 to 160 sheets, treating of about 80 species. The annual subscription price is $8.00. Subscriptions may be sent to G. E. Stechert, No. 9, East 16th street, New York city. Those persons or institutions desiring further information regarding this work, with samples of the plates, will be supplied on application to professor Charles Schuchert, Yale University Museum, New Haven, Conn. CHAS. SCHUCHERT.

THE TYPE OF AVICULIPECTEN. Commenting, in the September number of the AMERICAN GEOLOGIST, upon a note of mine regarding the type species of *Aviculipecten*, McCoy, Mr. Wheelton Hind finds just cause to regret that I had not, before writing, seen his monograph upon the Carboniferous Lamellibranchiata. It is so easy to overlook publications in these days of redundant literature, that one is loath to have the appearance of being thus at fault when really to a considerable extent blameless. Mr. Hind's monograph was one of the first works consulted when I undertook to ascertain the true characters of *Aviculipecten*. I was thoroughly sorry not to find, in the set to which I had recourse, the portion of his work dealing with that genus, and concluded, mistakenly as I now find, that it had not yet been published. A short time thereafter, when the work really did come before me, an effort was made to recall my manuscript for reconsideration, but it was found to have already passed the press.

The fact, as pointed out by Mr. Hind, that the names thus unwittingly used in my discussion turn out to be in many cases synonyms, is subordinate in importance to my conclusion that the typical species of *Aviculipecten* is a quite different one from that which he regards as such. He remarks upon this point: "I think, in the unfortunate circumstance of the absence of any definite indication, that it is a good and simple rule to regard the first described species as the type of the genus. All that Mr. Girty has to say as to the locality is important, but nevertheless an author has some object in view in the arrangement of his species, and as McCoy adopted no alphabetical order, we must presume that he intended *A. planiradiatus* to be the type." I think Mr. Hind must have written these words by oversight, for as I pointed out in my original note, McCoy elsewhere arranges his species alphabetically, and in the case of the paper containing the generic description of *Aviculipecten* also, the species, so far as their number in each case permits, are so arranged. This is true of the two species *A. planiradiatus* and *A. ruth-*

veni. Under the circumstances, therefore, the assumption that by the arrangement of the two new forms which he took that occasion to describe McCoy intended to designate *A. planiradiatus* (now, according to Hind, *A. tabulatus*) as the type of *Aviculipecten*, seems unjustified, especially since it is quite certain that *A. docens* (now, according to Hind, *A. semicostatus*) was the species which McCoy figured to show the structures of *Aviculipecten*, and which, according to his own statement, was the one that taught him the distinctive characters of the genus. It seems to me clear, therefore, that *A. docens* McCoy (=*A. flexuosus* McCoy=*A. semicostatus* Portlock) is the only species which with propriety can be considered typical of *Aviculipecten*.

GEORGE H. GIRTY.

PERSONAL AND SCIENTIFIC NEWS.

DR. EDWARD H. KRAUS has been appointed instructor in mineralogy at the University of Michigan.

AMONG THE TOPOGRAPHICAL MAPS recently issued by the United States Geological Survey are the following: Parkersburg, W. Va.; Vanceboro, N. C.; San Diego, Calif.; Apalachin, N. Y.; Boston, Mass.; Bastrop, Texas; Honeoye, N. Y.

JAMES WALTER GOLDTHWAIT, of Lynn, Mass., has been appointed instructor in geology in Northwestern University. Mr. Goldthwait took his college course at Harvard, where he has also done graduate work and where he has been for two years past teaching fellow.

THE FOURTH NEW ENGLAND INTERCOLLEGIATE GEOLOGICAL FIELD EXCURSION was held at Worcester, Mass., on Saturday, Oct. 22, under the direction of Mr. Joseph H. Perry of the Worcester High School. The excursion was attended by over forty persons, including representatives of Amherst, Harvard, Massachusetts Institute of Technology, Smith, Wellesley, Williams, Worcester Polytechnic, and Yale, and of St. Mark's School, Worcester Academy, Worcester High School and Worcester Normal School. A general statement of the problems to be studied was made by Mr. Perry on the evening before the excursion in the rooms of the Worcester Natural History Society. The field localities showed outcrops and quarries of slates and quartzytes, assigned to the Carboniferous period, greatly deformed and eroded, with many large and small granitic intrusions. An excursion to some point on the sea coast will probably be made next year.

UNITED STATES GEOLOGICAL SURVEY.

The Second Annual Report of the Reclamation Service, a volume of 550 pages with maps and illustrations, has recently been issued as House Document 44, fifty-eighth Congress, second session. This report contains an account of the results accomplished during the field season of 1903.

"Bibliography and index of North American geology, paleontology, petrology and mineralogy for the year 1903," by F. B. Weeks, has recently been issued as Bulletin No. 240.

The forthcoming volume on mineral resources contains, for the first time since 1898, tables showing the result of analyses and tests of building stones.

The coal and coke resources of the Latrobe, Pennsylvania, region are described by W. R. Campbell in Folio No. 110, which has been recently issued.

The magnesite product of the United States came last year entirely from California. Special mention of this substance is made by C. G. Yale in the "Mineral Resources for 1903."

THE NEW YORK ACADEMY OF SCIENCES, OCT. 17. The program of the evening consisted of a lecture by E. O. Hovey, on "St. Vincent, British West Indies. The Eruptions of 1902 and their immediate results."

The author gave a summary account of the results obtained on two expeditions undertaken by him for the American Museum of Natural History in 1902 and 1903, for the study of the volcanic eruptions of the Soufrière which began in May, 1902. Particular attention was devoted to the heavy coating of volcanic ash deposited upon the northern portion of the island of St. Vincent and the ash-filling of the gorges of the Wallibou and Rabaka Dry rivers, the devastation wrought in the forests and on the plantations within a radius of about five miles from the crater and the phenomena of primary eruptions observed in the crater and of secondary eruptions observed in the Wallibou and Rabaka ash-beds. The nature of the exploding eruption cloud was discussed and it was shown how the heavily dust-laden steam cloud kept close to the surface of the ground under the influence of gravity while its initial velocity was furnished by the horizontal component of the explosion.

About eighty lantern-slides were used in illustrating the speaker's remarks.

The result of ballot for officers was the election of E. O. Hovey for vice-president and chairman of the Section of Geology and Mineralogy, and Dr. A. W. Grabau of Columbia University for secretary.

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No. 3. Cliff on Rocky fork showing the entire Berea formation, capped by Sunbury shale. Photographed by Mr. J. E. Hyde.

No. 4. Wright quarry west of Portsmouth in which the even bedded sandstones of the Buena Vista member are finely shown. Its top is indicated by Mr. Wilkinson, above which are shown the shale and sandstone zones.

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No. 5. Complete thickness of Berea sandstone as shown on Hartman run. Photographed by Mr. Charles C. Wilcox.

No. 6. Berea sandstone with irregular base and Bedford shale below as shown on bank of Smith run. Photographed by Mr. Charles C. Wilcox.

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THE
AMERICAN GEOLOGIST.

VOL. XXXIV. DECEMBER, 1904. No. 6.

THE WAVERLY FORMATIONS OF CENTRAL OHIO.*

By CHARLES S. PROSSER, Columbus, Ohio,
Assisted by
EDGAR R. CUMINGS, Bloomington, Indiana.

PLATES XVII—XIX.

CONTENTS.

INTRODUCTION

From fifteen to twenty miles east and southeast of Columbus are interesting exposures of most of the formations composing the Waverly series. These formations are shown to no better advantage at any other place readily accessible from Columbus and heretofore these localities have been either very imperfectly described or not at all. A study of these rocks has furnished additional information regarding the character of the Waverly formations in central Ohio which is considered of sufficient interest to warrant publication. Some of the sections were first studied while engaged in areal work on the East Columbus quadrangle for the U. S. Geological Sur

* Published by permission of EDWARD ORTON, JR., State Geologist of Ohio.

vey in which Dr. Edgar R. Cumings ably assisted; but later they have been given a more thorough detailed study by the senior author.

The greater portion of the region under discussion is the hilly country in the northwestern part of Fairfield county and northeastern part of Pickaway. Although the edge of this hilly district in a direct line is only 15 miles or a little farther southeast of the Capitol in Columbus it has never been described. In many respects it affords the most satisfactory exposures of the Waverly formations to be found in central Ohio and on this account is of especial interest to the stratigraphic geologist.

The hills just enter the southeastern corner of Franklin county bordering Big run for about one mile, the northwestern limit of which is about four miles southeast of Groveport. It is really a plateau dissected by numerous small streams, giving the topography a somewhat rugged aspect and the excellent exposures of the various formations are due to the eroding agency of these streams.

The geology of Franklin county was described by Dr. Orton and the "Waverly group" is represented on the geological map of the county as crossing its southeastern corner,* but there is no account of the Waverly formations as shown in the broken country where Franklin, Pickaway and Fairfield counties corner.

LITHOPOLIS AND VICINITY

In the narrow glen running parallel with the main street of Lithopolis, Fairfield county, known as Leyndecker glen or Dutch Hollow, which forms the northeastern boundary of the village, occurs one of the best sections to be found in central Ohio for studying the relations of the lower formations of the Waverly series. The exposures begin with very soft argillaceous shales capped by compact, heavy beds of Berea grit at a distance of about one-half mile below the highway bridge crossing the glen. This lowest shale probably belongs at the top of the Bedford formation while the Ohio shale is not seen in the immediate vicinity of Lithopolis. It may be seen, however, on the banks of the Little Walnut creek at both crossings

* *Rept. Geol. Surv. Ohio*, vol. iii, 1878, op. p. 600.

on the roads from Canal Winchester to Lithopolis. The detailed section of this glen is given below.

Lithopolis Section

No.		Thickness.	Total thickness.
16.	*Cuyahoga formation.* Bank on western side of Joseph Leyndecker's quarry shows 14 feet of shales and thin sandstones to the soil on its top.	14′	114¾′
15.	Sandstone stratum, which on the eastern bank of the quarry is 1 foot 5 inches.	1′9″	100¾′
14.	Rather sandy shales with two or more thin sandstones, from 4 to 8 inches in thickness. This zone on the eastern wall is 5 feet 5 inches in thickness.	5′4″	99′
13.	Light gray compact sandstone which forms a prominent stratum on the banks of the quarry. It varies in thickness on the western bank from 1 foot 10 inches to 2 feet 1 inch, is 2 feet 8 inches on the southeastern and reaches 2 feet 11 inches in the eastern bank where it is very compact, but splits into two layers.	2′	93′8″
12.	Dark to bluish-gray rather sandy shale which is 3 feet in thickness on the eastern wall of the quarry, 3 feet 9 inches on the southeastern and 3 feet 6½ inches on the western wall.	3′6″	91′8″
11.	Top of ***Buena Vista member.*** Zone of two or three sandstone layers, alternating with shales, which is 4 feet 8 inches thick at the southern end of the western bank, 5 feet at the northern end of the same cliff and 6 feet on the eastern bank. The section at the southern end of the western bank from the base up is 3 inches sandy shale, 1 foot 10 inches quite massive sandstone, 1 foot 5 inches bluish argillaceous shale and 1 foot 2 inches sandstone; at the northern end of the same bank the lithology has changed as follows: 3 inches shale, 1 foot 1 inch sandstone, 1 foot 1 inch shale, 1 foot 2 inches sandstone, 4 inches shale and 1 foot 1 inch sandstone. On the southeastern wall the section of this zone from the base up is 5½ inches blue shale, 2 feet 5 inches sandstone, 1 foot 8 inches shale with 1 foot of sandstone at the top. The quarrymen tell me that the middle sandstone noted at the northern end of the western bank begins with a harder	5′+	88′2″

	layer of shale in the 20 inch shale stratum of the southeastern wall and gradually increasing in thickness could be followed, before the bank was partly covered by talus, from this point to the northern end of the quarry's western wall. The section of this zone on the eastern bank is as follows: 5 inches thin sandstone to shale, 1 foot 5 inches light gray sandstone, 10 to 11 inches dark gray argillaceous shale, 1 foot sandstone, 5 inches argillaceous shale, 1 foot 3 inches light gray sandstone and 8 inches sandy shale to thin sandstone. This zone is shown in Fig. 1 where Mr. Wilkinson's hand indicates its top while he stands on top of No. 10.		
10.	A massive, fine grained light bluish sandstone which is the most valuable stratum in the quarry, varying in thickness, as measured on the quarried blocks, from 3 feet 2 inches to 3 feet 9 inches, and the quarrymen report that it varies from 2 feet 6 inches to 4 feet 2 inches in thickness. This layer is a valuable freestone, and Mr. Leyndecker states that it received a prize at the Columbian Exposition at Chicago.	3'6"±	83'2"
9.	Banks of the creek below the covered bridge show that this interval consists of dark gray shales alternating with sandstones, which vary from 5 inches to 1 foot 2 inches in thickness. This is a rather difficult interval to measure with a hand level and the results differ somewhat; but the writer recently made it 25 feet and his assistant Mr. J. A. Wilkinson 27 feet 3 inches.	25±'	79'8"
8.	Sandstone stratum 1 foot 7 inches thick, 10 inches shale and heavy bluish sandstone stratum 2 feet 3 inches thick at base.	4'8"	54'8"
7.	Gray somewhat arenaceous shale, and thin sandstone layers.	4'2"	50'
6.	A heavy layer of blue, iron-stained sandstone, which forms a small fall in the stream and a little below may be seen on its eastern bank. In the fall about 8 inches of the sandstone remains which is shown in Fig. 2. This apparently corresponds to the "City Ledge" in the Ohio cliffs near Buena Vista.	2'10"	45'10"
5.	Gray argillaceous shale, which is very soft and gritless. On the bank of the stream a little	5'	43'

below the fall 4 feet 2 inches is shown and probably the thickness of the zone is a few inches greater. Mr. Cumings gave this shale as 5± feet and Mr. G. F. Lamb makes it just 5 feet. The base of the shale marks the base of the Cuyahoga formation.

4. *Sunbury shale.* Black, fissile shale, in very thin laminæ, considerably iron-stained on old exposures. A little above its contact with the Berea the shale forms a bank 15+ feet high on the western side, where some of it is rather grayish in color and softer than it is generally found. Farther up the stream on the opposite side is another 15 foot bank of black shale, above which is the mainly covered gray shale zone at the base of the Cuyahoga formation, capped by the overlying sandstone. The contact of the Sunbury shale and the shale zone at the base of the Cuyahoga formation, however, may be seen in the bed of the stream a short distance below the fall formed by No. 6 of this section. 28±′ 38′

In the bed of the stream, 3½ inches above the top of the Berea grit, is a thin, but very fossiliferous zone. This is the one almost universally found very near the base of the Sunbury shale and at this locality contains numerous specimens of *Lingula melie* Hall, some of a larger *Lingula*, *Lingulodiscina Newberryi* (Hall) Schuchert and fragments of fish. It is somewhat difficult to measure the thickness of the Sunbury shale with a hand level on account of the distance of the sights, but careful measurements by Messrs. J. E. Hyde and G. F. Lamb make its total thickness 28± feet.

3. *Berea grit.* The top of this sandstone forms the floor of the stream and a small rapid just below the base of the black shale. The upper part contains plenty of iron pyrites and ripple marks occur in the upper layers. The rock which is fairly coarse grained, gray in color, but greatly iron-stained on the weathered surface, forms a ledge on the eastern bank of the creek, just below a fence. On the bank 4 feet is shown, to which perhaps a foot or more ought to be added in order to reach the top of the sandstone in the bed of the stream. From 5′± 10′

	the base of the sandstone as exposed in the bed of the stream to its top 4 feet 8 inches is shown.		
2.	Very soft argillaceous shale, of drab color which probably is at the top of the Bedford shale.	3′	5′
1.	Covered to stream level.	2′	2′

Several important stratigraphic facts are brought out by a study of the Lithopolis glen and others to the southwest of that town which will now be discussed. In the first place it will be noted that there is a remarkable thinning in the Berea sandstone when this section is compared with the one on Rocky fork, where it has a thickness of 37 feet,* as shown in a vertical sec-

*In my former descriptions of Rocky fork there has been some uncertainty regarding the base of the Berea grit and its thickness (See *Journal of Geology*, Vol IX, 1901, pp. 217, 218 and Vol. X, 1902, pp. 276-278, 328.) In the latter paper a concretionary layer of sandstone—No. 2 of the section on page 278—was described, which showed a lithologic change from the clay shales of the Bedford, regarding the stratigraphic position of which there was uncertainty as to whether it should be included in the Bedford formation or regarded as forming the base of the Berea. In going up the stream this concretionary layer is clearly shown in the next cliff, on the same side of the stream as the one mentioned above, and then may be found at the base of the lower end of the cliff on the opposite bank and somewhat farther up the stream. Formerly the lower part of this cliff was covered with debris but the floods of the winter and spring of 1904 have swept it clean so that the bed rocks are shown to water level. The stratigraphy of this portion of the three cliffs is in harmony: the concretionary layer was carefully leveled from the middle to the upper cliff and found to occur at the same elevation; while the concretionary layer at the middle of the upper and lower cliff is so nearly at the same level that no difference could be noted in the barometric readings. It might be considered better by some to regard the base of the Berea as beginning with the sandstone No. 5 of the section on p. 278; but the thickness of the shale zone, Nos. 3 and 4 decreases as it is followed up the stream, apparently by the lithologic change of the upper arenaceous shales into thin sandstones, and hence it is believed preferable to consider the concretionary sandstone—No. 2— as marking the base of the Berea formation. The thickness of the shale zone is 10½ feet in the lower cliff, 7 feet 4 inches in the middle one, and 3 feet 4 inches in the upper. Near the lower end of the upper cliff an almost vertical wall gives 37+ feet as the total thickness of the Berea formation. The section of the cliff is as follows:

No.		Thickness.	Total thickness.
7.	*Sunbury black shale*, only base shown.	1′6″	41′8″
6.	Top of *Berea sandstone*. Mainly fairly massive sandstone.	15′8″	40′2″
5.	Alternating shales and sandstones, the layers of the latter 6± inches in thickness.	14′11″	24′6″
4.	Arenaceous shales with thin sandstone layers, lowest one with ripple marks.	2′9″	9′7″
3.	Shale zone with quite arenaceous shales at the top.	3′4″	6′10″
2.	Sandstone stratum at base of Berea formation which is concretionary in places.	6″±	3′6″
1.	Top of *Bedford shale*, which is bluish-gray and quite arenaceous at the top, 3+ to the bed of the stream.	3′±	3′

This cliff is shown in Fig. 3 where the lower student stands on top of No. 2, while the upper students indicate the top of the Berea sandstone.

The section published on page 276 of the former paper was measured near the upper end of this cliff, when the concretionary stratum was covered, and the shale at the bottom—No. 1—is the continuation of No. 3 of the section at the lower end of the cliff and therefore belongs in the Berea formation instead of the Bedford.

A later measurement near the upper end of this bank gave the following section:

tion of the bank of the stream, about two miles northeast of Gahanna and fifteen miles north of its exposure in the Lithopolis glen.

Second, in this and other glens to the southwest of Lithopolis the entire thickness of the Sunbury shale is shown, while the previously best known section in central Ohio, the one on Rocky fork, exposes only the lower eight feet of this shale.

Third, the close agreement in lithologic composition and arrangement of the strata in the upper part of the Buena Vista members and the succeeding beds as shown at Lithopolis and in southern Ohio.*

No.		Thickness.	Total thickness.
4.	*Sunbury shale* at top of cliff, where estimates of thickness vary from 2¼ to 3¼ feet.	3½′	40′
3.	*Berea sandstones*, the lower ones alternating with shales.	32′	36½
2.	Arenaceous and argillaceous shale.	4′	4½′
1.	Sandstone layer.	½′	½′

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*Buena Vista as the name of a geological division was first used by Dr. Orton in his report of Pike county and published in 1874. In this description he wrote as follows regarding what is now called the Cuyahoga formation: "The next division in ascending order has for its chief characteristic the well-known and very valuable quarries of the Waverly system that lie along the Ohio river below Portsmouth. This subdivision has a definite base, viz., the upper surface of the Waverly black slate [Sunbury shale] but there is no characteristic stratum that constitutes a convenient superior limit. As the most valuable of the building rock, however, that is furnished by this part of the series in southern Ohio occurs within fifty feet of the slate, these fifty feet next above the slate may be somewhat arbitrarily taken as a subdivision. It may be designated as the Buena Vista section—the name being derived from a locality on the Ohio river that furnishes a large amount of stone of unequaled quality" (*Rept. Geol. Surv. Ohio*, Vol. II, pt. I, p. 626). It is now proposed to revive this name, define the upper limit and use it for the lower member of the Cuyahoga formation.

Dr. Orton's usage of the term Buena Vista was not uniform, for in the general sections of the rocks of Ross and Pike counties in the same report the name was restricted to 10 feet of sandstone between which and the top of the Waverly black slate [Sunbury shale] was a shale zone 30 feet in thickness (Fig. 1, op. p. 615 and Fig. 2, op. p. 618). In the Ohio valley very near the base of the Cuyahoga formation is an excellent sandstone which has been quarried for many years in the vicinity of Buena Vista. This stratum was noted by professor John Locke in his geological account of Adams county and termed the "City ledge" on account of the great extent of its use in Cincinnati (*Second Ann. Rept. Geol. Surv. Ohio*, 1839, p. 264). In 1884 Dr. Orton apparently restricted the name Buena Vista to this stratum for he wrote "Grains and nuggets of pyrites appear in the shales associated with this sandstone, but are not very perfectly visible to the naked eye in the city ledge (the name now applied to the stratum proper of Buena Vista stone)" (*Rept. Geol. Surv. Ohio*, Vol. V, p. 602). The same statement by Dr. Orton also appears in the *Tenth Census U. S.*, Vol. X, 1884, "The building stones of the United States and statistics of the quarry industry," p. 198. In 1888, however, Dr. Orton apparently returned to the opinion expressed in the text of his report on Pike county for under the description of the Cuyahoga shale he wrote as follows: "By good rights the shale should suffer one more reduction at its lower extremity. Everywhere through the state there is found directly above the Berea shale, or at a short remove from it, a number of courses of fine grained stone. * * * * *

It would have been well if the thirty or forty feet containing these courses had been cut off from the Cuyahoga shale, in which case the division thus formed would have been well named the Buena Vista stone, but inasmuch as the series does not absolutely require the change, it is left unmodified" (*Rept. Geol. Surv. Ohio*, Vol. VI, pp. 37, 38: and the same statement was republished by Dr. Orton in 1895 in Vol. VII, on p. 31). Apparently in these last two accounts of the Geological Scale of Ohio Dr. Orton had forgotten that in 1874 in the Pike county report he had proposed that the fifty

Fayler run, a tributary of Big run, on the S. M. Oyler farm, about one-half mile west of Lithopolis, shows part of the Bedford and Sunbury shales and the Berea sandstone. The farm is on the road leading southwest from Lithopolis to the county line road and the exposures are to the northwest of the road and house. The section is a short one; but the run cuts through the entire thickness of the Berea sandstone as is shown below:

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feet of sandstone and shale succeeding the Waverly black slate [Sunbury shale] should be "designated as the Buena Vista section." At the time of the preparation of my paper on the Sunbury shale of Ohio I had overlooked the Buena Vista section so proposed by Dr. Orton in the text of the Pike county report and at that time I thought he had definitely applied the name Buena Vista sandstone *only* to the "City ledge" or what was considered its equivalent and hence I used the name in that sense (See *Jour. Geol.*, Vol. X., 1902, pp. 288-292). Prof. C. L. Herrick in 1891 in his Portsmouth section gave the "Flags of Buena Vista" with a thickness of 25 feet (*Bull. Geol. Soc. Amer.*, Vol. II, p. 40).

Since the stratigraphic term Buena Vista was used by Dr. Orton with at least two values, it is necessary to make a selection and its definite application in the Buena Vista section of the Pike county report to the fifty feet of shale and sandstone overlying the Waverly black slate (Sunbury shale) is the one which has been adopted. This will designate the lower portion of the Cuyahoga formation which in at least central and southern Ohio contains valuable layers of building and construction stone and may very appropriately be regarded as forming a lithologic division which is designated the *Buena Vista member* of the Cuyahoga formation.

In southern Ohio the upper part of the member contains a variable number of even bedded sandstones which are extensively quarried and to this zone apparently professor Locke applied the term "beautiful quarry" on account of "the perfect parallelism, and, in many instances the uniformity of the thickness of the strata" (*Second Annual Rept. Geol. Surv. Ohio*, 1839, p. 264). In the Ohio valley the top of this zone of even bedded quarry stone is apparently a definite and well marked stratigraphic horizon above which are thicker beds of shale with sandstone which is not valuable for quarrying. This contact is admirably shown in the quarry of Mr. John Wright about 2¼ miles up Carey run from the river road after crossing the Scioto valley west of Portsmouth, and is shown in Fig. 4, where Mr. Wilkinson is pointing to the top of the Buena Vista member.

Succeeding the quarry stone is a zone of blue to olive shale three feet or more in thickness, then a zone of shale and sandstone varying from 2+ to 3+ feet in thickness, both of which are clearly shown in Fig. 4, above which is a conspicuous argillaceous shale zone about 5 feet in thickness. The lithologic similarity of this part of the section was found to remain quite constant in the various quarries and outcrops studied in the hills for several miles below Portsmouth. The top of the Berea sandstone and the Sunbury shale are nicely shown in Stony run, several miles below Portsmouth. About three-fourths of a mile up the run, a bank and the James Amlin quarry gave the thickness from the top of the Sunbury shale to the top of the quarry stone as 48½ feet. This thickness of 48½ feet for the Buena Vista member is in close agreement with Dr. Orton's original statement of fifty feet. Professor Andrews gave the thickness of what is regarded by the writer to represent the Buena Vista member as 75½ feet (See his "Section of Waverly rocks from the Great Black Slate to the Sub-Carboniferous Limestone, as seen on the Ohio river," on "Maps showing the Lower Coal Measures" in *Geol. Surv. Ohio*, pt. II *Rept. Prog. Sec. Dist.* [in 1869], 1870.): but in this part of the section is the statement that a sandstone and shale interval of 29½ feet was not measured and it is thought the thickness of this interval was over estimated.

At Lithopolis it is more difficult to accurately measure the thickness of the Buena Vista member than at the locality cited below Portsmouth; but at the former locality Nos. 5 to 11 inclusive of the section are referred to the Buena Vista with an approximate thickness of 49¼ feet. A recent measurement of this member by Mr. George F. Lamb gave 51 feet 11 inches.

Succeeding the even bedded quarry stone at the top of the Buena Vista at Lithopolis is a conspicuous shale zone capped by a sandstone which is in striking agreement with the section below Portsmouth.

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No.		Thickness.
3.	*Sunbury shale*, thin laminated black shale only the base of which is shown in the run, but higher in the field 20¾ feet.	20′9″
2.	*Berea sandstone.* Thin, irregular bedded brownish to rusty colored sandstone, 3 feet 7 inches on the northern bank and 4 feet 2 inches on the southern.	3′7″
1.	*Bedford shale.* Upper part is bluish-gray soft argillaceous shale. A little farther down the run near the base of the exposure is some mottled gray and faintly chocolate colored shale.	13′6″

SECTIONS SOUTHWEST OF LITHOPOLIS

Big run, the largest southern tributary of Little Walnut creek, crosses the county line road near where Franklin, Pickaway and Fairfield counties corner. Bedford shale is soon reached on this stream when it is followed above the county line road crossing, considerable of which is of reddish color. Less than half a mile above the road crossing on the land of Mrs. L. J. White, the western bank of this run is about 35 feet high and composed entirely of Bedford shale. The lower nine feet is chocolate to mottled in color, while the remaining part is mostly grayish. In the shale about 18 feet above the stream level is a large concretion. The shale in the bed and banks of the stream from the base of the cliff just described to a point above the second branch from the east is mainly reddish in color.

Hartman Run Section

The first branch from the east, a few rods above the high western bank, is on the land of Mrs. S. E. Hartman and may be called Hartman run. It gives the following section:

No.		Thickness.	Total thickness.
7.	*Cuyahoga formation.* Alternating beds of grayish fine grained sandstone and bluish argillaceous shales are shown for some distance up the run.	21	80′8″
6.	Fairly massive, grayish, argillaceous sandstone which has been quarried to a slight extent.	5′+	59′8″
5.	Drab, very soft argillaceous shale which measures on the bank 3 feet 11 inches. Base of *Cuyahoga formation.*	4′—	54′8″

4.	*Sunbury shale.* Black, thin, even layered shale, the base resting on sandstone at top of cascade. About two inches above the base a thin layer containing *Lingula melie* Hall and *Lingulodiscina Newberryi.* (Hall) Schuchert.	23'—	50'8"
3.	*Berea sandstone.* A massive ledge of somewhat coarse grained grayish sandstone below the Hartman barn, which is shown in Fig. 5. A little above, it makes a small cascade in the run where 6 feet 3 inches is shown, in which two layers show ripple marks.	6'+	27'8"
2.	Drab, soft very argillaceous shale just below the sandstone, which is probably the top of the Bedford shale. Most of this interval covered.	16'8"	21'8"
1.	Chocolate and mottled shale to the level of Big run.	5'±	5'

Smith Run Section

About one-eighth of a mile to the southeast of the Hartman run is a similar and parallel one on the farm of Mr. Smith, which may be called the Smith run. On the bank of this stream is shown the entire thickness of the Berea sandstone and also above, that of the Sunbury shale in a shorter distance than in the Hartman run so that the conditions are more favorable for measurement. The section is as follows:

No.		Thickness.	Total thickness.
6.	*Cuyahoga formation.* Sandstones alternating with shales, some of the sandstone layers a foot or more in thickness.	22'	81'
5.	Two layers of sandstone in similar stratigraphic position to that of the "City ledge."	4'4"	59'
4.	Bluish-gray argillaceous shale which varies in thickness from 5½ to 6 feet. Two feet four inches below the top of the shale is a 3½ inch layer of sandstone.	5'6"	54'8"
3.	*Sunbury shale.* Thin, even layered black shale which is well shown in the narrow portion of the glen. About 3½ inches above its base *Lingula melie* Hall, *Lingulodiscina Newberryi* (Hall) Schuchert and fish scales occur. Another measurement gave 20 feet 10 inches for the entire thickness.	20'8"	49'2"
2.	*Berea sandstone.* A prominent ledge of sandstone on both sides of the run of variable thickness ranging from 3½ to 7 feet on the	6'6"	28'6"

northwest bank, and perhaps 6½ feet is near the thickness of the main part. The base of the sandstone on this bank is not a uniform line and the underlying shale to the level of the run varies in thickness from 6 to 9 feet. This character is shown in Fig. 6. The weathered ledge is much stained, rusty to brownish in color and the upper part contains much marcasite as is generally the case in the various sections reported.

1. *Bedford shale.* Bluish-gray to gray in color, on the bank beneath the Berea sandstone; but down the run are mottled and reddish shales before reaching Big run. 22′ 22′

On the western bank of Big run above the mouth of Smith run and the house of Mrs. Nancy Cole is a ledge of the Berea sandstone, although it is not so well shown as in the two glens just described. Drift and boulder clay fill the valley of Big run above the ledge of Berea sandstone, so that the Sunbury shale is not shown.

Along the stream about one mile southwest of Big run and parallel with it, exposures of Ohio shale commence where the stream and highway cross the Franklin-Pickaway county line one and one-half miles west of the Fairfield county line. The shales are uniformly black, even, highly fissile and weather brownish. They are exposed almost continuously for one-half mile up the stream, although at no place rising more than about ten feet in the stream-banks, with a thickness of forty feet, according to barometric readings. One-half mile up the stream the Bedford shale appears, almost in contact with the Ohio shale, and where it first appears there is an exposure of fifteen feet, the lower part of which is bluish, the middle portion mottled and the upper five feet dull red in color. The texture of the shale is typical, being gritless, much jointed and passing rapidly into small flakes or into a stiff clay. About two feet of Berea sandstone is shown near the head of the south fork of this run.

Along the east and west road one mile south of the Franklin-Pickaway county line, at a point just one mile west of the Fairfield county line is another exposure of the Berea which at this locality is a brownish, coarse grained sandstone, two

and one-half feet of which is shown but neither the top nor bottom.

The large stream which heads on the Fairfield-Pickaway line about one and three-fourths miles south of the Franklin-Pickaway-Fairfield corner and flows nearly west through a narrow ravine affords exposures of nearly all the Bedford formation. The shale usually rises only a few feet in the banks of the stream of which it often forms a clean cut bed; in places, however, it forms banks fifteen or twenty feet in height. The shale is invariably red, sometimes mottled with grayish-blue and may contain concretions of considerable size. The soil in places at some distance from the stream is reddish in color and contains fragments of the red shale. In this locality, therefore, the drift cover over the divides is apparently not deep. The upper part of the Bedford in this area is usually red and not mottled or grayish as to the east and northeast of Columbus. The stream to the north of the one just described affords very good exposures of Bedford shale of similar lithologic appearance.

Section Northwest of Marcy

One-half mile north of Marcy post-office is the source of a stream flowing west and northwest, receiving as eastern tributaries the small streams just mentioned, and emptying into Little Walnut creek two and one-half miles north of St. Paul, Pickaway county. The upper course of this stream is through a narrow glen cut in the Cuyahoga, Sunbury and Berea formations on the farm of J. M. Hensel. The following section is shown on this stream:

No.		Thickness.	Total thickness.
5.	*Cuyahoga formation.* Blue, fine-grained sandstones with some intercalated soft gray shale which contains very little grit. At the base are thin bedded sandstones with shales and shaly sandstones, above which are shales containing concretions.	25′+	66⅔′
4.	Gray argillaceous shale which is very soft and gritless, with the exception of a 6 inch compact gray sandstone the base of which is 3 feet 2 inches above the base of the shale. This zone is well shown on the northern bank of	8⅔′	41⅔′

	the creek a few rods below where the top of the gray shale is seen in the stream's bed.		
3.	*Sunbury shale.* Thin, black, laminated shale. The contact of the gray shale at the base of the Cuyahoga is beautifully shown in the bed of the stream with an inch layer of mottled, black shale, the mottling due to cylindrical ramose, infilling of gray material similar in appearance to the gray shale above. The line of contact between the gray and black shale is perfectly distinct and sharp. The base of the black shale is in contact with the subjacent sandstone, the lowest layer of which is arenaceous, strongly pyritiferous and contains *Lingula melie* Hall, which is common, *Lingula* sp. and plants. On the southern bank of the stream a little above the Berea ledge is a bank of Sunbury shale 22 feet high by tape measure, and the highest exposure of shale by hand level is 26 feet above the top of the Berea. The second exposure up the stream above the one just described, which is on the northern bank, shows 12 feet of Sunbury shale capped by 9 feet of shale and the latter by a sandstone. The base of this exposure by hand level is from 12 to 14 feet above the top of the Berea sandstone. A recent measurement of this shale by Mr. George F. Lamb gave 24 feet 8 inches.	26′	33′
2.	*Berea sandstone.* Coarse, gritty, bluish sandstone in a single stratum which varies in thickness from 1 to 6 feet. In the stream where the contact with the Sunbury shale occurs it is only a foot or a little more in thickness; but on the bank 50 feet below it increases to 6 feet and then thins when followed a few yards down the stream to 2 or 3 feet. The upper part of the sandstone contains plenty of marcasite and its top surface is even, so that the irregularity is in the lower surface. Other exposures in the vicinity show as great a thickness as 10 feet.	6′±	7′
1.	Gray fine grained shale, iron-stained, containing occasionally lenticles of sandstone; but in general a soft argillaceous shale which in places is nearly a clay. At this locality it varies in thickness, according to thickness of the Berea sandstone, from less than a foot to 5 feet.	1+′	1′

Farther down the stream are outcrops of the reddish Bedford shale below which are excellent ones of the Ohio shale, which in places forms banks from 30 to 40 feet in height. This shale may be followed for a mile along the creek to the four corners where are good exposures both east and west of the road bridge, fifteen feet or more in height, very clean cut and characteristic.

The stream to the north of the one just described gives perhaps the best exposures of the Bedford shale for this region; below which is the Ohio shale.

WATERLOO AND JEFFERSON

On the southern bank of Little Walnut creek, just east of the covered bridge three-fourths of a mile southeast of Waterloo on the George Loucks' farm is an exposure of twenty feet of red Bedford shale. This outcrop extends to water level and is capped by the Berea grit, which forms a small ledge on the bank of the creek at this locality. This exposure shows that in this region the red color of the Bedford shale extends nearly to the base of the Berea grit. This bank of red shale is about one mile south of the Hocking Valley railroad.

Chestnut ridge, two miles east of Lithopolis, forms a conspicuous feature of the landscape in a region of such uniformly low relief as that of central Ohio. The ridge is composed of a coarse grained, yellow, massive sandstone which is the base of the formation so conspicuously shown in the Hocking valley twelve miles to the southeast, near Lancaster. This ridge is, therefore, geologically and topographically the outlier of the picturesquely eroded cliffs and slopes which give to the Hocking valley its beautiful scenery.

Jefferson Section

At the northern end of Chestnut Ridge is the small village of Jefferson to the south of which on the hill is the quarry of Mr. J. E. Cross. The following section was obtained commencing at the rear of the school-house yard and extending up the hill to the top of the quarry:

No.		Thickness.	Total thickness.
10.	Soil.	5′	156′
9.	Rather thin bedded brownish to yellowish sandstone. Fairly massive stratum at the base.	10′	151′

8.	Apparently two layers of yellowish sandstone similar to the zone below with a shaly sandstone to shale a little above the middle.	14′	141′
7.	Massive stratum of yellowish, coarse grained sandstone, which is friable.	8′	127′
6.	Iron-stained sandstone, irregular, somewhat shaly, and contains pockets of shale.	2′4″	119′
5.	Light gray to bluish coarse grained sandstone.	1′8″	116′8″
4.	Sandstone similar to the zone above.	4′	115′
3.	Covered to base of quarry.	46′	111′
2.	Alternating shales and thin sandstones which are bluish at the base, becoming more iron-stained and coarser toward the top, shown along quarry road. *Cuyahoga formation.*	60′	65′
1.	Covered from school yard.	5′	5′

In the above section the shales and sandstones of No. 2 belong in the Cuyahoga formation, while the rocks from No. 4 to the top of the quarry apparently belong in the lower part of the Black Hand formation.

From the base of the Cross quarry to the base of the Berea sandstone on the southern bank of Little Walnut creek to the southeast of Waterloo the barometer gave a difference in elevation of 200 feet. The latter locality is one and one-fourth miles farther west than the Cross quarry while the dip in this region is about 20 feet per mile to the east. As the thickness of the Berea sandstone and the Sunbury shale at Lithopolis is 33 feet it indicates that the Cuyahoga formation in this section has a thickness of about 200 feet. Estimates made in other localities in this general region indicate a thickness ranging from 200 to 250 feet for the Cuyahoga formation.

EASTERN FRANKLIN COUNTY

In the eastern part of Franklin county near Blacklick and Reynoldsburg and on Blacklick creek are exposures of the lower formations of the Waverly series. This region has neither been very carefully described nor the formations in all cases correctly identified.

Blacklick Creek and Village

On the eastern bank of Blacklick creek a little above the Broad street pike crossing and one mile below the railroad bridge at Blacklick, is a good outcrop of the Sunbury black

shale, the upper eight and one-half to ten feet of the formation being shown. The complete section is as follows:

No.		Thickness.	Total thickness.
4.	Soil to top of bluff.	8′	28′8″
3.	Soft bluish sandstones, weathering gray and strongly iron-stained, which are medium thin bedded.	2′	20′8″
2.	Gray very soft, gritless shale with an arenaceous layer near the middle. The line between this shale and No. 1 is very clear and sharp.	10′2″	18′8″
1.	*Sunbury shale.* Very thin, laminated, black smooth shale which weathers to small sharp edged flakes.	8′6″	8′6″
	Creek level opposite sycamore tree.		

A little farther down the creek about ten feet of the Sunbury shale is shown. The lower exposures are on the farm of Frank Milburn and to the north on the farm of J. W. Miller. The Sunbury shale is shown for some distance up the stream and after a covered interval of about one-half mile its last appearance is on the J. K. Black farm, where on the eastern bank a few rods below the swing bridge one foot is shown. On the same side of the creek a little below is a higher bank in which the lower Cuyahoga sandstones occur. The Black farm was formerly owned by E. Compton and this is undoubtedly the locality where Dr. Orton stated that the contact of the Huron and Waverly formations is shown.* It is to be noted, however, that the black shale is the *Sunbury* instead of the Huron (Ohio).

Perhaps rather more than one-quarter of a mile up the creek are exposures of higher rocks on the Frank Cornell farm which was formerly that of S. R. Armstrong. About east of the Presbyterian church in the southern part of Blacklick village on the western side of the creek is a partly covered sandstone bank, below which is shown the upper half of the soft shale zone at the base of the Cuyahoga formation. At low water the lower part of the shale zone is shown a little farther down the stream and the following section may be obtained:

* *Geol. Surv. Ohio*, vol. iii, 1878, p. 639.

No.		Thickness.	Total thickness.
11.	Soil to top of bank 5 to 10 feet.		
10.	Mainly thick to thin bedded sandstone, buff to gray and iron-stained on weathered surface, but blue to gray on fresh fracture.	30′	55′
9.	Mostly covered, occasional outcrops of sandstone commencing about 12 feet above the base of this zone.	19′6″	25′+
8.	Layer of hard, bluish-gray sandstone, coarser grains than in the thin layers below; 6 inches shown in the bank and covered above, so that the layer is probably thicker.	0′6″	5′7″
7.	Blue argillaceous shale.	0′3″	5′1″
6.	Hard layer of fine grained sandstone of rusty color as weathered.	0′1½″	4′10″
5.	Soft argillaceous bluish shale, which has very little grit.	2′5″	4′8½″
4.	Thin sandstone, similar to lower one, from 2½ to 3 inches in thickness which weathers rusty on its edge.	0′2½″	2′3½″
3.	Bluish argillaceous shale.	0′10-″	2′1″
2.	Fine grained argillaceous sandstone, bluish-gray in color and perhaps slightly calcareous.	0′3″	1′3″
1.	Very argillaceous shale, bluish as low as exposed in creek.	1′-	1′

The barometer gave an interval of five feet from the base of this section to the top of the Sunbury shale on the Black farm. The shales and thin sandstones from No. 1 to 7 inclusive with a thickness of five feet one inch are regarded as representing the upper half of the soft shale zone at the base of the Cuyahoga formation which, with the five foot interval to the Sunbury shale, has a thickness of ten feet one inch at this locality. It will be noted that this thickness is in close agreement with that of the same zone described in the section three-fourths of a mile farther down the creek in the bank above the Broad street pike, where it is ten feet two inches. Again the fall in the creek from the shale bank below the Presbyterian church to the Sunbury shale bank above the Broad street pike is about fourteen feet so that the bed of the stream at the former locality would be about five and one-half feet above the top of the Sunbury shale.

A few rods farther up the creek than the section just described is a conspicuous steep, rocky bank on its eastern side

in which the Blacklick Stone Company has opened during the last two years a somewhat extensive quarry. This quarry is but a few rods below the railroad bridge and furnished the following detailed section:

No.		Thickness.	Total thickness.
14.	Mainly covered, but occasional layers of sandstone shown in run to the northeast of the quarry for 15 feet above its top. No indication of black shale in run.	15'	61'
13.	Three layers of buff sandstone alternating with shale and extending to the top of the quarry bank.	2'2"	46'±
12.	Yellowish-gray shale, 3 to 4 inches in thickness.	0'3"	43'11"
11.	Probably top of the *Buena Vista member*. Buff, friable sandstone similar to lower thick stratum.	1'2"	43'8"
10.	Shale parting.	0'1"±	42'6"
9.	Buff sandstone appearing as a massive stratum which splits into thin layers on the weathered surface; somewhat friable.	5'	42'5"
8.	Partly bluish shale and in part buff, rather thin bedded sandstone.	6'8"	37'5"
7.	Grayish, compact massive sandstone.	2'1"	30'9"
6.	Blue shale.	1'1"	28'8"
5.	Gray massive sandstone.	1'1"	27'7"
4.	Mainly bluish shale with some rusty, thin sandstone.	3'10"	28'6"
3.	Buff, compact sandstone.	1'10"	24'8"
2.	Layers of bluish-gray to gray sandstone, 16 inches and thinner, alternating with bluish shales. Some of the sandstones are considerably iron-stained or rusty in color. Present floor of quarry.	14'10"	22'10"
1.	Partly covered. Buff sandstone at the base in bed of stream which is apparently the one just above the shale zone near the base of the Cuyahoga formation, or No. 8 of the section farther down the creek. At this point below the sandstone is about 3 inches of bluish shale below which is a thin somewhat concretionary sandstone similar to No. 6 of the lower section.	8'+	8'
	Creek bed.		

If to the above section of sixty-one feet the ten foot zone of shale with thin layers of sandstone, at the base of the Cuyahoga

formation be added, it will give seventy-one feet of the lower part of that formation. There is not such a sharp lithologic break in this quarry as in the Lithopolis one; but perhaps as marked a lithologic change as any is to be found at the top of No. 11, or the first sandstone layer overlying the thick sandstone near the top of the quarry. The top of No. 11, therefore, has been provisionally selected as the top of the Buena Vista member, which will give it a thickness in this section of fifty-three feet eight inches, which is four feet four inches more than in the one at Lithopolis.

Just below the railroad bridge is an old quarry in which some work has been done during the last two years. The section of the eastern bank is as follows:

No.		Thickness.	Total thickness.
10.	Mainly thin sandstone alternating with argillaceous shales, none of the sandstones apparently thick enough for use.	7′+	41′
9.	Buff sandstone, probable top of the *Buena Vista member.*	0′7″	34′+
8.	Shale parting.	0′1″-	33′6½″
7.	Buff sandstone, which in places splits into two layers.	1′1″	33′5½″
6.	Shale to sandy parting.	0′3½′	32′4½″
5.	Massive layer of buff sandstone which is much rusted or iron-stained in places and considerably on the surface. Somewhat friable, but these older exposed surfaces are not so friable as in the new openings in the lower quarry. This stratum is conspicuously shown on both sides of the creek below the railroad. The top of this sandstone by the hand level apparently corresponds with the top of the heavy layer, or No. 9, of the lower quarry. Thickness varies from 6 feet to 6 feet 3 inches.	6′	32′1″
4.	Rather buff sandstones, the upper ones containing numerous specimens of *Spirophyton,* alternating with bluish shales.	4′11″	26 1″
3.	Bluish shales.	1′	22′2″
2.	Thick layer of sandstone, considerably iron-stained in many places. This layer is No. 7 of the lower quarry.	2′2″	21′2″
1.	Bluish to bluish-gray sandstones alternating with shales, one layer 1 foot 11 inches in thickness, but most of the sandstone layers are 10 inches or less in thickness.	19′	19′
	Creek level.		

The massive layer (No. 5 of the above section) is seen near the top in all the sections in the vicinity of Blacklick varying in thickness from 4 to 6 feet. The fall in the creek from the railroad bridge to the shale bank, below the Presbyterian church is about nine feet which, therefore, makes the top of the section at the railroad bridge about fifty-seven feet above the base of the Cuyahoga formation. The top of the Buena Vista member in this section was drawn provisionally at the top of No. 9, which would make its thickness in this section about fifty feet. The highway to the east affords occasional outcrops of sandstones similar to those seen in the banks of the creek at Blacklick.

Two miles to the southwest of the Blacklick railroad bridge the railroad cut at Taylors exposes rather thin bedded sandstones. These sandstones are buff in color, with rather friable texture like that of the Berea sandstone, they show plenty of ripple marks and some of the layers are contorted or concretionary in structure. About one-fourth of a mile to the west, small gullies show the presence of the red Bedford shale, some of the soil is reddish and two brick plants use this shale which is obtained from quarries located some distance north of the railroad on the Andrew Morrison farm. The stratigraphy and lithological characters apparently show conclusively that the sandstones in the railroad cut at Taylors belong in the Berea formation.

The topographic map gives the elevation of the railroad cut at Taylors as nearly nine hundred feet and the nine hundred foot contour line extends up Blacklick creek to the railroad bridge, so that the bed of the creek at Blacklick and the railroad cut at Taylors have about the same elevation. Hence, the easterly dip of twenty feet or more per mile must carry the sandstones shown in the railroad cut at Taylors below the bed of Blacklick creek at the village of Blacklick.

Dr. Orton in the "Report on the Geology of Franklin county" mentioned ten feet of bedded sandstones in the railroad cut at Taylors which he called "the sandstones of the lower Waverly,"* evidently referring them to that division of the Waverly group which he called the "Wavery quarry system." †

* *Rept. Geol. Surv. Ohio*, vol. iii, 1878, p. 638.

† For the classification of the Franklin county Waverly, see p. 689 of the report cited above.

The writer has already shown that this division is the same as the Berea sandstone,* hence the correlations of the sandstones shown in Taylors railroad cut are in harmony. The identification, however, of the rocks shown in the "section of Waverly sandstone at Armstrong's quarries, Blacklick station,"† is erroneous. The writer has shown that the Waverly shales of the Franklin county report are the upper portion of the Bedford shales.‡

The ten feet of Waverly shale, however, given at the base of Dr. Orton's Blacklick section is not the top of the Bedford shale but the zone of soft shale at the bottom of the Cuyahoga formation which has been described in this paper at the exposures on Blacklick creek above the Broad street pike crossing and below the Presbyterian church in Blacklick. The overlying forty-eight feet, ten inches of sandstones and shales in this section referred to the Waverly quarry system (=Berea sandstone) instead of being the Berea belongs in the lower part of the Cuyahoga formation. Apparently this quarry is referred to the Berea grit in the Tenth Census "Report on the building stones of the United States, and statistics of the quarry industry for 1880," compiled from notes of Dr. Orton.§

Reynoldsburg and Vicinity

On the bank of a small run a short distance east of Reynoldsburg, about opposite a street turning south, on the Sam Chamberlain farm is an outcrop showing the top of the Sunbury shale and the lower part of the Cuyahoga formation. The section is as follows:

No.		Thickness.	Total thickness.
4.	Thin bedded, grayish sandstone with perhaps a shale zone in this interval; partly covered.	4′±	17¾′
3.	Greenish-gray sandstone containing numerous specimens of *Spirophyton*, which on weathered surface tends to split into thin layers but probably under cover it is massive. A loose block on the bank is 1 foot 9 inches in thickness, its top covered with fucoid (?) mark-	1¾′+	13¾′

* *Jour. Geol.*, vol. ix, 1901, p. 218.

† *Rept. Geol. Surv. Ohio*, vol. iii, p. 641, which are described on pp. 639 and 640.

‡ *Jour. Geol.*, vol. ix, 1901, p. 217.

§ Vol. x, 1884, p. 195. Also republished in *Rept. Geol. Surv. Ohio*, vol. v, 1884, p. 595.

	ings; the basal sandstone of the Cuyahoga formation.		
2.	Upper part of shale zone gritty, below which it is argillaceous and 4 feet below the top is a somewhat gritty and coarser band. The lower 6 feet drab, soft argillaceous shale which is apparently without grit.	10′±	12′
1.	*Sunbury shale.* Black fissile shale to bottom of the run.	2′±	2′

A few rods to the west is another run on the same farm, which flows southerly, on which a few yards above its mouth is shown eight feet of the upper Sunbury shale; but none of the clay shale at the base of the Cuyahoga formation. A little farther up the run is another outcrop of the Sunbury shale under a clump of trees.

About one and one-half (?) miles to the northeast of Reynoldsburg is the Wm. A. Forrester quarry, which he has worked for forty years. The following section was obtained at this locality:

No.		Thickness.	Total thickness.
15.	Rather thin bedded sandstones of light gray color, which on weathered surface are brownish gray or iron-stained, that alternate with thin layers of shale. Thickness 8 to 10 feet.	8′+	75′
14.	Sandstone zone which is more or less solid.	3′	66′10″
13.	Olive shale.	.8″	63′10″
12.	Sandstones which weather to a brownish-gray or iron-stained color, alternating with shales.	9′4″	63′2″
11.	"Block layer" of quarrymen from 1 foot 3 inches to 1 foot 6 inches in thickness, which stains badly on weathering and is not used. Shale parting.	1′4″	53′10″
10.	Bluish-gray sandstone.	0′3½″	52′6″+
9.	Blue shale.	0′1″	52′3″
8.	Bluish-gray sandstone. This and the sandstones above discolor badly on weathering.	0′3″	52′2″
7.	Blue arenaceous shale.	0′2″	51′11″
6.	Probable top of *Buena Vista member.* Three courses of bluish-gray sandstone, each one 8 inches in thickness, which are fairly soft, and are sawed into flagging. These sandstones do not discolor on weathering.	2′	51′9″
5.	Arenaceous shale to thin sandstone.	0′10″	49′9″
4.	Bluish-gray sandstone, which contains vertical tubes like worm borings.	1′9″+	48′11″

3.	Similar bluish-gray sandstone.	2′2″±	47′2″
2.	Bluish-gray sandstone (freestone of quarrymen) which cuts well. This layer and the two superjacent ones are sawed into flagging, window sills, etc. This layer sometimes splits into two, the upper one 2 feet in thickness. Mr. Forrester considers this layer identical with the massive 3½ foot layer (No. 10) in the Lithopolis quarry.	3′4″	45′
1.	Mainly covered down the stream to the top of the Sunbury shale, with the exception of the section described on the Chamberlain farm. Mr. Forrester stated, however, that in one part of the quarry they went down 30 feet below the bottom of the quarry and found the rocks blue sandstones alternating with "soapstone" (shale), but not valuable for quarrying.	41′8″	41′8″

On the northern bank of the quarry, which is the old wall, it is twenty-six feet from the top of No. 6 to the top of the exposed rocks, or two feet and nine inches more than on the eastern and newer wall of the quarry. This gives about 78 feet of rocks exposed above the top of the Sunbury shale all of which belong in the lower part of the Cuyahoga formation. It is to be noted that these rocks are the same as those exposed on Blacklick creek at Blacklick with more than twice the thickness of the entire Berea formation on Rocky fork, five miles northwest of this section. The change in lithology from the rocks referred to the Buena Vista member to the overlying ones is not so conspicuous as at Lithopolis; but the line has been provisionally drawn at the top of the three courses of eight inch sandstones or No. 6. The sandstones of No. 6 and lower ones are bluish-gray from which there is a considerable change to the overlying grayish sandstones which weather to a rusty color. The rocks, however, overlying the Buena Vista member contain a much larger proportion of sandstone than is found in the similar part of the section at Lithopolis. This section gives the Buena Vista member a thickness of fifty-one and three-fourths feet which agrees quite closely with the fifty-three and two-thirds feet of the Blacklick section and the forty-nine and one-third feet of the Lithopolis section.

A well was drilled near this quarry, which, according to Mr. Forrester's record, began near the top of No. 6 and at a depth of forty feet reached what he called soft mud. This mud

was probably the shale zone at the base of the Cuyahoga formation in which case the well record of forty feet from the top of the Buena Vista member to the shale agrees closely with the forty-one and three-fourths feet of the above section. Below the soft shale the well passed through black shale and then entered sandstone to the distance of two feet. The distance from the top of the soft shale to the top of the sandstone, according to Mr. Forrester, is 20 feet and the sandstone below the black shale is apparently the Berea grit.

SECTION SOUTHEAST OF NEWARK

Investigations made during the last two years have changed considerably my ideas regarding the lower limit of the Black Hand formation, as exposed to the southeast of Newark, and the results will now be briefly stated.

The following section is compiled from outcrops in Havens' quarry, down Quarry run to Licking river, the first run to the east and the cliff farther east near the house of Mrs. Mary M. Stasel which is one and one-fourth miles east of the Court House in Newark:

No.		Thickness.	Total thickness.
10.	Alternating shales and sandstones to the top of the east wall of Havens' quarry.	14′	175½′
9.	Fairly massive buff sandstones.	16′	161½′
8.	Bluish shales; base of *Logan formation.*	5′	145½′
7.	Top of *Black Hand formation.* Grit stratum varying in thickness from 10 to 13 inches. Conglomerate II of Herrick.	1′	140½′
6.	*Allorisma* shales.	7′4″	139′6″
5.	Massive buff freestone, lower part thin bedded to shaly layers.	28′6″	132′2″
4.	Rather coarse quartz pebble conglomerate which varies in thickness. Conglomerate I of Herrick. In the run below Havens' quarry 3 feet 8 inches is clearly shown, although the thickness is somewhat greater (4 feet 11 inches in a former measurement when it was exposed to better advantage). On the Stasel cliff buff sandstones alternate with layers of grit and conglomerate with a thickness of about 7 feet 11 inches of which the following is a detailed section:	3′8″	103′8″

	Feet.	Inches.
Conglomerate	2	1
Grit		9
Sandstone		9
Conglomerate		9
Shaly sandstone		9
Grit		7
Sandstone		8
Conglomerate	1	5
Total	7	11

3.	This interval down Quarry run is mainly covered, except at the base where 11 feet of massive buff sandstone is shown. In the first run east, however, 21 feet of buff rather coarse grained sandstone is shown at its base and on the Stasel cliff about 35 feet of similar sandstone directly underlies Conglomerate I. Several barometric readings give the difference in elevation from the base of the coarse grained sandstone on Quarry run to the base of Conglomerate I on the same stream as from 55 to 65 feet, so that the rocks for the greater part of this interval are shown.	60′	100′
2.	*Top of Cuyahoga formation.* Mainly bluish-gray arenaceous and argillaceous shales with some alternating layers of sandstone which are occasionally a foot or more in thickness. On west bank of Quarry run there is a buff sandstone stratum 1 foot 7 inches in thickness. Fossils occur in this part of the formation. The lowest shales are exposed in the bed of the run just above Summit street bridge.	30±′	40′
1.	Covered interval to level of Licking river.	10′+	10′

In the above section the Black Hand formation has a thickness of 100½ feet. When my former paper was written the Stasel cliff and coarse sandstones in the two runs to the west had not been seen by the writer and it was supposed that shales occurred directly below Conglomerate I as had been described by professor Herrick for the Newark region.* Hence the base of this conglomerate was regarded as the base of the Black Hand formation.† The present section shows that to the east of Newark, coarse grained buff sandstones extend for

* *Bull. Denison Univ.*, vol. iii, 1888, p. 26, and *Ibid.*, vol. iv, 1888, pp. 100, 105, 106.

† *Jour. Geol.*, vol. ix, 1901, p. 224.

about sixty feet below the base of Conglomerate I, at which horizon is the most marked lithologic change in the rocks, and the base of these sandstones has been selected as the line of division between the Black Hand and Cuyahoga formations.

In the quarries southeast of Newark the most marked lithologic change in the upper part of the formation occurs at the top of the massive freestone (No. 5). In professor Hicks' original description of the formation he included in it, overlying the compact drab sandstone, a "Fucoid layer" seven to twelve feet in thickness and a "coarse sandstone and conglomerate" three to eighteen feet in thickness.* It is thought that the Fucoid layer represents the *Allorisma* shale of Herrick and the top sandstone and conglomerate Herrick's Conglomerate II. For the above reason Conglomerate II has still been considered in the sections of the Newark quarries as the top of the Black Hand formation.

The continuation of the section from Havens' quarry is to the eastward up "the gorge," which is the stream that joins Quarry run some rods to the north of the quarry, along which is shown, according to the barometer, about ninety feet of buff arenaceous shales to thin bedded sandstones to the base of the Sharon conglomerate. The shales predominate in the lower thirty feet of the section and apparently about the lower ten feet are shown in the upper part of the Havens' quarry wall. These rocks and those of the Havens' quarry succeeding Conglomerate II or No. 7, are referred to the Logan formation which has a thickness in this section of about 115 feet.

The thickness of 100½ feet for the Black Hand formation in the above section agrees closely with that of the formation in the vicinity of Clay Lick, seven miles east of the Newark section. On the Bell farm one-half mile east of Clay Lick, the formation is well exposed on the point just east of the house. The barometer gave 85 feet from the B. & O. railroad up to the top of the ledge of coarse grained rock (mainly grit) with some pebbles which are arranged somewhat in layers and occur from the top to the bottom. It is mainly of yellowish color, but with some brownish and an occasional reddish layer. In the creek at Clay Lick are coarse sandstones apparently belonging in the Black Hand formation which barometrically

* *Amer. Jour. Sci.*, 3d ser., vol. xvi, 1878, p. 218.

give it a thickness of 100+ feet. The thickness is in close agreement with professor Herrick's statement that "one-half mile east of Clay Lick there is a nearly continuous exposure of about 100 feet of alternating conglomerate and coarse sandstone of prevailingly red color."*

THE UNTENABLENESS OF THE NEBULAR THEORY.

By N. Mistockles, Minneapolis, Minn.

III.

(*Continued from page 319.*)

THE RELATION OF THE EXCENTRICITY IN THE ORBITS OF THE PLANTS TO THEIR SIZE AND THEIR DISTANCE FROM THE SUN; HOW THE MOONS HAVE COME TO THE PLANETS.

The scientific investigator often discovers that matters to which he has before paid but little attention on account of their apparently small significance, prove to be of decisive importance in arriving at a correct understanding of the law or natural phenomenon which he is studying. This we ourselves shall experience before we close this chapter; for we shall find that the solution of a very comprehensive problem concerning the arrival of the moons to the planets depends greatly on a correct conception of the excentricity of the planetary orbits, to which, in general, but little attention has been paid. Let us, therefore, preliminarily, proceed to the discussion of this subject, in order, thereby, to gain a better understanding, than would otherwise be possible, of matters depending thereon.

The excentricity of the orbits of the planets stands in relation to the size of the planets and their distance from the Sun. The truth of this statement may not be readily ac-

* *Bull. Sci. Lab. Denison Univ.*, vol. ii, 1887, p. 15.

cepted, perhaps, since it is contrary, in part at least, to all accepted astronomical theories. But he who seeks a solution of problems presented by natural phenomena, must not pay too much attention to existing theories, nor must he fear the authorities; for these will, in most cases, oppose the most self-evident truths, if they find their own theories in danger. History teaches us that. We admit, however, that the conservatives have a perfect right to stand by and defend the old ideas until the new ones have been presented and established. But the trouble is, that many of these conservatives shut their eyes to the truth and will not allow themselves to be convinced. According to Flammarion the Academy of Cortona unanimously declared the discovery of Jupiter's moon to be an optic illusion; and Libri, a philosopher in Pisa, would not condescend to put his eye to the telescope to see Jupiter's moons. There is nothing of the kind to be feared in the present instance, however.

According to the nature of the excentricity, as stated above, it follows, that a small planet, even close to the Sun, has a very excentric orbit, while the orbit of a large planet, quite far from the Sun, has a small excentricity. The planets Mercury and Jupiter may be mentioned as illustrating this point. The former has an average distance from the Sun of 36 million miles and its diameter is 3,200 miles; but it has an orbital excentricity of more than 7 million miles and varies about 15 million miles in its distance from the Sun. The latter planet, on the other hand, has a distance of 480 million miles and is 88,000 miles in diameter, while its orbital excentricity is only 23 million miles. It follows, then, that in Jupiter's orbit Mercury would have reached an excentricity of about 90 million miles or more; and that Jupiter, if he were 300 million miles nearer the Sun, would have no excentricity. Venus, the Earth, and Mars may serve as further examples to explain this point. The first of these, which has a distance from the Sun of 67 million miles and is of about the same size as the Earth, has an orbital excentricity of not quite 500,000 miles, while the Earth's orbit, which is 26 million miles farther from the Sun, has an excentricity of one and one-half million miles. The little planet Mars, on the other hand, which is 141 million miles distant from the Sun and which is only 4,200 miles in

diameter, varies over 26 million miles in it's distance from the Sun.

We find that the same rule applies to the more distant planets. Saturn, having a distance of 867 million miles from the Sun and a diameter of 76,000 miles, varies in its distance about 100 million miles. Uranus, with a distance of 1,765 million miles and a diameter of 32,000 miles, varies 176 million miles in its distance. Finally we come to Neptune, which seems to make an exception. His average distance from the Sun is figured to be 2,764 million miles and his diameter is calculated to be 37,000 miles, while the variation in his distance is accepted to be the same as that of Jupiter, that is, about 50 million miles. But the astronomical calculations may easily be erroneous in this case. I am confident that the variation in Neptune's distance amounts to about 200 million miles. I shall produce proofs later, which will make the matter clear and show my opinion to be correct. In the meanwhile it is important to take notice of the calculations of Adams and Leverier concerning the perturbations of Uranus. Both of them ascribe great excentricity to the disturbing planet, Neptune, and there is reason to believe that the excentricity, which was found as a result of these men's calculations, which also led to the discovery of Neptune, is more correct than the one accepted by modern astronomers and based on the third of the so-called Kepler's laws. We must remember, that the reasonable correctness of this law for the inner part of the solar system does not guarantee its correctness in an unlimited application, for which reason it may not hold good as to the most distant planet and cannot be safely applied unless we have other things to go by. Bode's law held good for all the planets until it was applied to Neptune when it proved to be not even approximately correct. But these matters we shall, as before said, take up and discuss later on. Let us, however, in connection with these remarks direct our attention to the fact that to the present time there have been discovered about 500 small planets between Mars and Jupiter, which have a variation in their distance of from 100 to 200 million miles, which shows that the excentricity of the planetary orbits everywhere stands in relation to the size of the respective planets and their distances from the Sun. We may, therefore, con-

clude with reasonable safety, that what in this respect is true of all the planets from Mercury to Uranus and which also holds good as to hundreds of minor planets, will, no doubt, hold good also as to Neptune.

§15 HOW THE MOONS HAVE COME TO THE PLANETS.

It appears clearly from what we have already said, that the relation with regard to age in which one planet stands to another, cannot be determined by the planet's distance from the Sun, since their origin is independent of that body. As we have shown, further, that no heavenly body appears originally with a satellite, the moon has, consequently, been developed out of a nebula different from that of the Earth, and has at some time revolved around the Sun. The moons of the other planets have commenced their existence in the same manner, that is, as free bodies circling around the same center of force. But how, then, has it happened that these little bodies have been captured by the larger ones, and lost their original orbits?

In §12 it was pointed out that the excentricity of the planetary orbits depends on the size of the planets and their distances from the Sun.

We have mentioned that Mercury's diameter is about 3,200 miles, its orbital excentricity somewhat more than seven million miles, and its distance from the Sun 36 million miles; also that its aphelion distance from the Sun is about 15 million miles greater than its perihelion distance. From this it follows, that the Moon, which has a diameter of 2,160 miles, would, if it had Mercury's average distance from the Sun, and in obedience to the law of excentricity, have a greater orbital excentricity than Mercury. We understand, thus, that if the Moon had an orbit of about double the distance of Mercury's from the Sun, it would have an excentricity of rather more than 12 million miles or thereabout, and it would reach about 25 million miles farther from the Sun at aphelion than at perihelion. But now the question is this: Was the distance of the Moon somewhere between 70 and 80 million miles?

Inasmuch as it was not captured by Venus, it must have occupied a place so far outside of this planet, that it did not

reach her orbit at perihelion, which shows that its distance from the Sun must have been more than 70 million miles.

It is, indeed, possible, that its average distance from the Sun reached 100 million miles, and that it had its orbit outside of the Earth; but the most reasonable assumption is, that its average distance from the Sun was about 80 million miles, and that it, thus, reached several million miles outside of the Earth's orbit at aphelion.

Now since the Earth's nebula appeared inside of the Moon's aphelion-distance and outside of its average distance from the Sun, the Moon could not, for any length of time, escape crossing the orbit of the Earth to or from aphelion. The result would have been exactly the same, if its orbit had been just outside of the Earth's since this would have occasioned the Earth to have caught it at perihelion.

In this manner, then, the Moon was captured and became the satellite of the Earth, which the following illustration will serve to make clear.

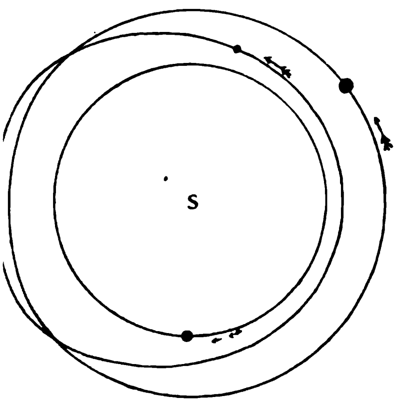


FIG. 1.
The orbits of Venus, the Moon and the Earth, respectively, around the Sun.

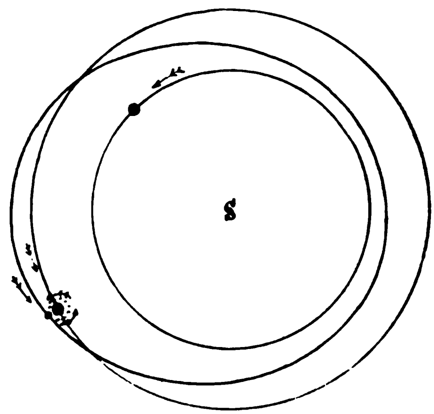


FIG. 2.
The Moon captured by the Earth.

We have spoken of the Moon as a planet when the Earth appeared as a nebula. It may be argued against this, that we lack proofs. If so, it is most fair to remark, that observations establish nothing more clearly than that the Moon is older than the Earth. Besides, it would not affect the result if either the Earth or the Moon is the older, for even if the Earth had been a planet when the Moon assumed the shape of a

nebula, the orbital excentricity of the latter would have been the same and the Earth would have been just as much in its way, and it could not in any way have escaped to become the Earth's satellite, provided it crossed or reached up to its orbit.

If the reader has paid careful attention to our argumentation against the nebular theory, he will the more easily understand, that this is absolutely the only way in which the Moon can have come to the Earth. If we consider Mars and his moons, it is equally clear, that wherever these exceedingly small planets had their orbits between Mars and the Earth and so far outside of the latter that they did not reach its orbit at their perihelia, they would, on account of the great excentricity of their orbits, cross or reach the orbit of Mars at their aphelia, and thus not escape being captured in the same manner that the Moon was captured by the Earth.

We may, then, safely conclude that what is true about the satellite of the Earth and of Mars is true also of the satellites of other planets to the uttermost limit of the solar system. If a large nebula would arise between Mars and Jupiter, where a large number of small planets with great excentricity have their orbits, it is clear that it, with its more circular orbit, would get a great number of moons.

It may be urged in opposition at this point, that there are no small planets beyond Jupiter; but since such an objection, if it were made, could not be based upon anything else than that we have, so far, not discovered any small planets beyond Jupiter, it would be of no avail. In reply, it would be sufficient to call attention to the fact, that before Piazzi discovered Ceres on January first, 1801, there was not a single small planet known in that region, where since that time about 500 have been discovered. In view of this, we understand, that before the discovery of Ceres, a statement might have been made with as great, or still greater force, that there were no small planets beyond Jupiter or Saturn or farther out. Such an objection is, therefore, not worthy of serious attention. We must, furthermore, be on our guard, both here and elsewhere, against limiting the scope of scientific development by barriers based only on ignorance and preconceived opinions.

As the number of discovered minor planets has increased from time to time, these have also been discovered farther and

farther away from the Sun, until they have now been found to exist near to the orbit of Jupiter. There is, therefore, no reasonable ground on which any one can claim, that such planets may not exist beyond the most distant one which has been discovered. This forces us to admit, that minor planets may be found outside as well as inside the orbit of Jupiter. When it is admitted, further, that if a small planet would intersect or reach the orbit of Jupiter, the result would be, that the lesser planet would be attracted to the larger at a point where their orbits cross each other or somewhere in that vicinity, then it is practically admitted, that this is the manner in which this mightly planet may have received its many moons.

It may be of interest now to find out how near one of the minor planets might approach one of the great ones, Saturn, for instance, in order to be captured by it. Astronomers have figured out mathematically that one of Saturn's moons would have to recede a distance of 30 million miles before the planet would lose it. It follows, then, that a small planet coming within that distance would be attracted by Saturn.

It may be, that this distance is rather large, and we shall therefore, try to determine it also on a different basis and compare the result with that given above. Let us consider, for this purpose, the relation in which the velocity and distance of Neptune stand to the distance and motion of Mercury, which will give us the diminution of the Sun's attraction in proportion to the increase of the distance. Next we may apply the same principle to Saturn's moons, and thus determine fairly accurately the limits which we wish to know. The distance of Neptune is 77 times that of Mercury, the velocity of the latter is 29 English miles a second and that of the former 3.2. This shows that the power of the Sun's attraction in the orbit of Neptune has fallen to one-ninth of what it is in Mercury's orbit. In considering the satellites of Saturn, let us take, for instance, the fifth one, Rhea. This has a distance of 336,000 miles, according to Flamarion, and a sidereal period of 4 days, 12 hours and 25 minutes, which gives it a velocity of 323.5 English miles a minute. By multiplying the given distance by 77 we find the distance from the planet to be 25,-872,000 miles. At this distance the power of attraction has, thus, fallen to one-ninth of what is in Rhea's orbit. Further,

if we divide Rhea's velocity, 323.5 miles a minute, by 9, we find that 35.8 miles a minute would be the velocity by which a moon would move around Saturn at a distance of about 26 million miles. Now since this is still nearly the velocity of the Moon around the Earth, it seems that a moon would revolve around Saturn at a considerable greater distance than 26 million miles. It appears, thus, that the mathematical computation mentioned above has come very close to the truth. We need not go to any extreme, however; it is satisfactory to know, that we have assured ourselves of the fact, that Saturn can overpower and attract small planets within a radius of at least 26 million miles.

The discovery of Saturn's ninth moon by professor Pickering in 1899 and the fact that this moon still has a distance of 8 million miles most strongly indicates that Saturn may have received its moons in the manner which we have now described. This appears still clearer when we remember that the small planets, which have an average distance from the Sun of 600 to 700 million miles, intersect the orbit of Saturn at their aphelia, and those which have an average distance of 1,000 to 1,200 million miles will intersect it at their perihelia; besides that, Saturn himself varies his distance about 100 million miles, and sweeps along in his orbit with a gravitative sphere so great that it measures about 56 million miles in diameter within which no small planet can come without being captured.

Having now come to an understanding of this matter, we understand also, that the two most distant moons, especially, are continually being drawn closer to the planet, and that the one farthest away is attracted most rapidly. The last one may, for all we know, just have been captured when it was discovered. But it is also possible, that it began its revolution around Saturn at a distance of about 20 million miles or more. Moreover, it is good reason to believe that small planets which yet have their orbits around the Sun, will in the future be discovered as moons of Saturn; and we may also conclude that what is true about Saturn in this respect is true about the more distant planets also.

Finally it may be of some importance to call attention to the fact, that the attraction which Saturn exerts on its distant

moons is the combined attraction of himself and his inner moons. This latter factor is of considerable importance, since one of the moons, Titan, is of about the same size as the planet Mars. This is true of all large planets with many moons and of the Sun as well as the planets. The velocity of Uranus, for instance, which is 258 miles a minute, would be about 300 miles less a day, if it were not for Jupiter.

As answer to the question, how near a small planet must come to Jupiter in order to be attracted by him we need only call attention to the fact that Jupiter is two-fifths stronger than Saturn, and that the power of the Sun's attraction is about two-eighths stronger in his orbit than in Saturn's. From this we find, that Saturn, if placed in Jupiter's orbit, would have lost about two-eighths or 7 million miles of the radius within which he can now attract smaller planets, and that Jupiter himself exercises this influence at a distance of about 35 million miles in all directions from his center.

If we next direct our attention to the most distant planets and notice that Neptune exerts a disturbing influence on the large planet Uranus, which is 1,000 million miles nearer the Sun, we find this natural order no less self-demonstrating. Since we know that Neptune disturbs Uranus, it is easy to see what the result would be, if a small body, say about the size of our Moon, being $^2/_{1000}$ of Uranus, came within a few million miles of Neptune. Its capture as a moon would be absolutely certain.

§16. The number of moons of the distant planets must, as a rule, stand in relation to the size of those planets and their distance from the Sun, no matter whether the moons have been discovered or not. The reason for this is a combination of several causes. As one of these causes we notice the increasing sphere of a planet's attractive power as its distance from the Sun increases. A second cause is the increase in the orbital excentricity of all the planets in proportion to their size and their distance from the Sun. A third factor is found in the circumstance, that the orbits of the minor planets are more analogous to the orbits of the larger ones the greater the distance from the Sun: this, again, being caused by the diminution of the power of the light-stuff,

which causes the large inclination of the orbits of the minor planets to the ecliptic between Mars and Jupiter, but which diminishes as the distance from the Sun increases. We may mention, also, as a fourth factor of somewhat minor importance, that the large comets, far from the Sun, may at times, draw the minor planets out of their orbits and thus put them in danger of being captured afterwards by the major planets.

Let us remember, then, that the small planets that reach the orbit of Neptune at their aphelia, reach or approach near the orbit of Uranus at their perihelia; and that the same class of bodies, which reach Uranus at their aphelia, reach in many cases, Saturn at their perihelia. This shows clearly that the small planets far out in the sea of ether, where the large planets rule, run a greater risk of being captured than those in the vicinity of Jupiter. Those large distant planets have for the same reason, greater opportunities to enrich themselves with moons than, for instance, Jupiter has. This opportunity becomes still greater by reason of the fact that the minor planets out there move in orbits analogous to the major ones and are, consequently, subjected to the attraction of these for a greater distance of their orbits than is the case in the inner part of the solar system.

The reader will then, finally, remember the fact, that a smaller planet which reaches or intersects the orbit of a larger one cannot escape being captured eventually by the larger one and being made its satellite; and that this has at some distant time happened to the Earth's Moon, and, in fact, to all the moons of all the planets.

(*To be continued.*)

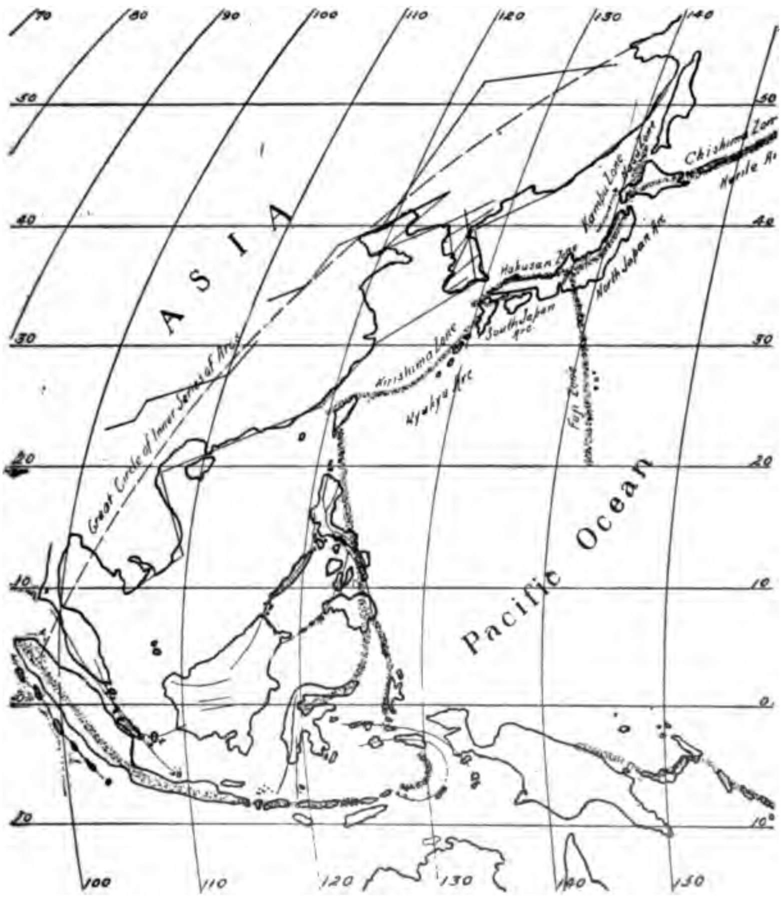
TECTONIC GEOGRAPHY OF EASTERN ASIA.

V.

Reviews and Translations by
William Herbert Hobbs, Madison, Wis.

(Concluded.)

In earlier numbers of this series there have been reviewed or translated recent papers dealing with the tectonic geography of the eastern border of the continent as well as special papers treating of Korea, Manchuria, and Japan. There remain for consideration the Riukiu (Loochoo) Islands, Formosa (Taiwan), the Philippines, and the complex of islands to the south



and west, which with the Philippines have together been designated as the Malayan Archipelago. In taking up for consideration this remaining portion of the region, the tectonic sketch map of Fig. 1 will serve for orientation. It has been constructed from several maps. On the main land of Asia the great series of arcs and the dominant lines of faulting have been entered from von Richthofen's studies. The tectonic lines sketched in for the Korean peninsula and about the gulf of Pechili are from dominating ones which appear upon the maps of Koto and von v. Cholnoky. The volcanic zones and the arcs in Japan have been taken from the new official map of Japan issued by the Japanese government and from v. Richtofen's sketch map, and the last mentioned author has been followed in Formosa and the Riukius. In the Philippines and other portions of the Malayan Archipelago the data have been furnished by the maps of Suess and Koto. The volcanic zone to the eastward from the Malayan Archipelago is entered from Berghaus's excellent *Atlas der Geologie.*

Riukin Arc: The island of Formosa and the island arc which connects it with Japan (Riukiu or Loochoo arc) has been made the subject of a special paper by v. Richthofen*, a paper based largely upon the monographs by Yamasaki† and Yashiwari‡; both of which papers contain excellent maps, the first mentioned of Formosa and the other of the Riukius. It has already been pointed out that the double series of arcs upon the continent border is paralleled by a third series that is outlined by the festoons of islands which inclose shallow seas and are surrounded by great ocean deeps. This latter and seaward series seems to end southward at Formosa, the structure of which appears to be of a different nature, and which is succeeded to the southward by more contracted series of arcs, extending, as Suess has shown, as far as the bay of Bengal.

The Riukiu islands arc while convex toward the sea appears to have a different character from the arcs to the northward. If one joins upon the map the islands of the outermost

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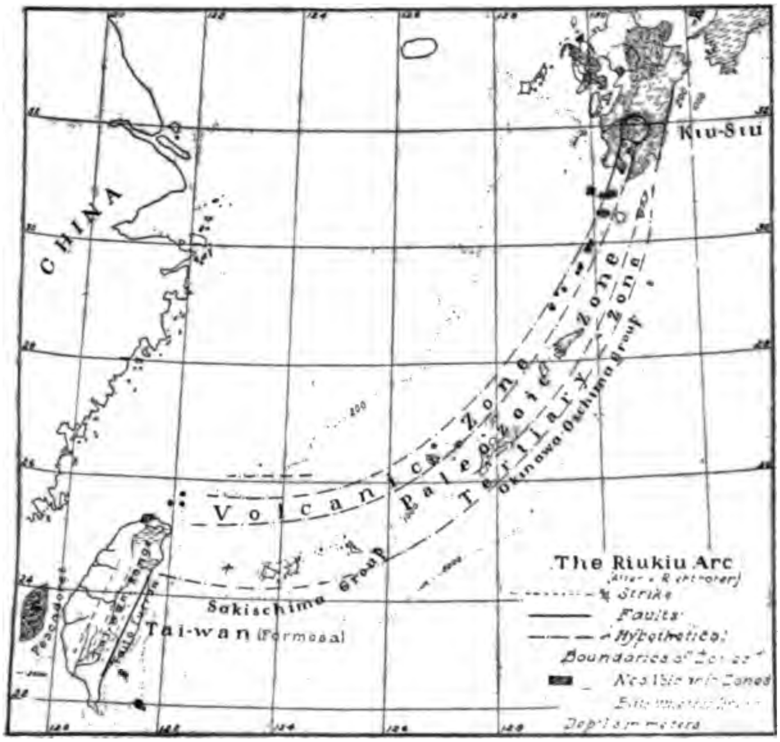
* Von. Richthofen: Geomorphologische Studien aus Ostasien, III, Die morphologische Stellung von Formosa und den Riukiu-inseln. Sitzungsber. d. k. pr. Akad. d. Wiss. z. Berlin, vols. 39 and 40, 1902, pp. 944-975, with pl. 3.

† Dr. N. Yamasaki: Unsre geographischen Kenntnisse von der Insel Taiwan (Formosa). Peter. Mitth., vol. 46, 1900, pp. 221-284, with plate 19.

‡ S. Yashiwari: Geologic structure of the Riukiu (Loochoo) curve and its relation to the northern part of Formosa. Jour. Coll. Sci. Imp. Univ. Tokyo, vol. xvi, art. 2, 1901, pp. 3-67, with five plates.

series and in like manner the innermost projecting points of the larger islands, the two nearly parallel lines of arcs are obtained, which are distant from each other about 60 k. m.—the breadth of the island zone. (See Fig. 2.) To the southward this dis-



tance is, however, contracted to less than 34 k. m. The interior of the two arcs consists of older, presumably Palaeozoic sediments, which are intruded by granite. The outer arc, on the contrary, is occupied by rocks of Tertiary age. The zonal structure of the double arc and the conformity of the strike of the rocks to the direction of the arc, as well as the constant dip of the beds toward the inner side, render it probable that fold structures, perhaps accompanied by overthrusts, may be largely responsible for these areal peculiarities. Landward from the double belt of islands and closely following its inner margin, runs the zone of new volcanic islands which are strung like pearls upon a string. To the southward the outer Riukiu arc

is interrupted by later cross dislocations within the Sakischima group, which is the southernmost in the belt and meets the eastern coast of Formosa in the high and steep peninsula of Domkaku. From v. Richthofen's map, it would appear that the arc where it enters Formosa marks a dividing line between dominant strike directions to the northward and southward, and finds here its southward end.

To the northward the arcs are joined to Kiusiu, the southernmost of the Japanese islands, and continued upon it, the outer arc by a great fault along the eastern coast of the island, and the volcanic zone in the great *Graben* depression bounded by high and steep walls and terminated northward by an amphitheater (Kesseleinsenkung). In the bottom of this depression are located important volcanic vents. This important depression separates the two southern wings of the Palaeozoic basement.

Formosa: Following the Chino-Japanese war, by which the Japanese came into possession of Formosa, an exploring expedition was sent out in 1896, and what had before been known to science chiefly through its aspects from the sea gradually came to be fairly well known. It had been observed that the eastern coast was very steep and was backed by high mountains, two of which received from navigators the names Sylvia and Morrison. The western aspect of the island, on the contrary, was one of flatness. The sharply serrated eastern high range slopes away to the flat western coast. One of the most important discoveries was the remarkable "Taito furrow," which sharply cuts off upon the east the connected massif of ancient rocks along an almost straight line 155 k. m. in length and directed N 20° E. This furrow is occupied by three distinct streams separated by low divides, two streams passing out at the ends of the furrow, while a third intermediate and T-shaped one escapes through a gorge in the eastern range. This eastern range is known as the Taito range. Between the Taito furrow and the similarly directed line about 50 k. m. to the westward, runs the dominating Taiwan range, with its peaks Sylvia, Kantaban and Morrison, respectively about 11,000, 9,000 and 13,000 feet in height. These peaks also are in a line running N 20° E. Farther west follows a range consisting of Tertiary rocks likewise directed N 20° E. V. Richthofen adds:

"The significance of the strike given, N 20° E, as determining the structure of the Taiwan range, is even more sharply brought out when one considers an always important factor in the estimation of mountain structure, viz., the courses of the small head streams. . . . It is easy to see that the valleys, so far as they follow the longitudinal direction, strike N 15-20° E., and, what appears to be characteristic of parallel structure, they are many times joined to the trunk streams through short cross stretches."

In the northeastern part of the island, however, the direction of the ranges and likewise the strike of the beds is east-westerly, or almost at right angles to that of the large southern portion. This east-westerly structure would seem, moreover, to correspond more nearly to the extension of the Riukiu arcs. The volcanic zone of the Riukius also extends along the northern coast of Formosa in confirmation of this view. West of Formosa, however, the volcanic Pescadores islands trend in a direction N 15° E and conform to the tectonic lines as well as to the strikes within the greater part of Formosa.

In the transverse dislocations and in the abnormal strike directions characteristic of the southern or Sakischima group of the Riukius, von Richthofen sees a parellel to the case exemplified by the island of Crete in the Mediterranean, which while clearly a part of an arc that comes out from the Peloponnesus has tongues of land projecting northward into the sea from the western portion of the island, and these are explained by cross faults and *Graben* depressions along them.

To sum up, the Riukiu arc and the arc fragments of Formosa differ from the arcs of the continental series for the reason that in the meridional arms, the strikes characteristic of the fold structures accord with the lines of depression (Absenkungslinien), whereas, the rule upon the continent is that in the meridional arms arc-like dislocations quite generally cut across the prevailing strike. In conclusion the author says:

"The facts are augmented which for a series of different arcs lying to the north of the parallel of 22° in eastern Asia, allow of the conclusion that the normal structure of those parts of each individual arc which are included in the equatorial components, has been brought about before that of the meridional components; and that after the arc-like closing together, both the tectonic processes which after subsequent longitudinal depressions and disruptive longitudinal fractures gave to the meridional arms the normal form, extended over in the equatorial arms to the arc next adjacent upon the north, bringing about there abnormal cross dismemberment and transverse fracturing."

The Philippine Islands: It is unfortunate that we should possess so little knowledge of the geology of the Philippine islands. After six years of occupation by the United States the only reports published are those by Becker* which review the scattered papers, mainly in foreign languages, which at different times have referred, however cursorily, to the geology of the Philippine islands.

Of great interest, however, and especially so because of our meagre knowledge, is the collection of ores, minerals, and rocks which have been gathered from many sources and placed upon exhibition in the Philippine Mines building at the St. Louis Purchase Exposition. With the knowledge that valuable deposits of coal (including good steam coal), iron, and copper occur in the islands, and that some of these are soon to be vigorously exploited, it seems unlikely that the geological examination of the islands can be much longer delayed. The importance from a strategic as well as from an economic standpoint, of developing these deposits it would seem would be generally appreciated. For our knowledge of the structure of the islands, we are especially indebted to Austrian† and Japanese‡ geologists.

In the paper on the island world of southeastern Asia, Koto has included a brief section upon the Philippines, which, meagre as it is, contains important conclusions regarding the areal and geologic structure of the islands. In the larger archipelago of which the Philippines form a part, mountain ranges and chains of volcanoes radiate from the inner group, which consists of the islands of Borneo, Celebes, and Gilolo. These mountain ranges comprise parallel ridges, separated by tectonic valleys, one of which extends from the bay of Butuan to the bay of Davao in Mindanao, and another from the bay of Lingayen to Manila, so as to separate the main Luzon chain from the westerly Zambales. The volcanic zones and the prin-

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* George F. Becker: Brief memorandum on the geology of the Philippine Islands. U. S. Geol. Surv., 20th Ann. Rep., pt. ii, pp. 3-7, 1900.
George F. Becker: Report on the Geology of the Philippine Islands. U. S. Geol. Surv., 21st Ann. Rept., pt. iii, pp. 493-614. This paper includes a list of sources and a translation of C. Martin's paper concerning Tertiary Fossils in the Philippines (pp. 615-625.)

† Suess: Antlitz der Erde, vol. i, 1885, pp. 585-588; vol. ii, 1888, pp. 206-217; vol. iii, 1901, pp. 308-332, plate II.

‡ Koto: On the geologic structure of the Malayan archipelago, Jour. Coll. Sci. Imp. Univ. Tokyo, vol. ii, pt. ii, 1899, pp. 83-120, with plate I.

cipal tectonic lines of the archipelago as they have been made out by Koto, have been indicated in figure 1.

Becker*, after a careful review of the literature, expresses the opinion that too much effort has been made to show unbroken continuity of the volcanic zones in the archipelago, and adds:

"Fissures occur far more often in parallel systems than singly, and just as dikes frequently jump from one fissure of such a system to another, so, I think, do the greater volcanic phenomena. Fissures, furthermore, commonly occur in two systems, cutting one another at a large angle, and there are somewhat clear indications that such is the case with the volcanic belts in the Philippines south of Manila. These two systems are approximately parallel to the two prongs of Masbate, but each is curved, the centers of curvature lying in the China sea, one of them much to the southward of the other. I should consider, provisionally, that the elevations of northwesterly trend, such as the mountains of eastern Mindanao, Leyte, Tayabas, Mindoro, northwestern Panay, and perhaps the northern extremity of Palawan, belong to the one system, but represent a considerable number of different though associated fissures. The trends of the northeasterly character also seem to belong to one system. The western fork of Masbate appears to continue to northeastern Panay, but to be interrupted with an offset in the southwestern portion of that island. The southerly prolongation, it seems to me, is to be found in the Cagayanes. Of course Palawan, Negros, excepting the southern end, and the Basilian-Jolo group belong to this system. So nearly as I can make out by plotting, the two systems intersect at pretty constant angles of about 60°. A fairly consistent and satisfactory scheme of short arcs can be arranged in this way for the ranges south of Manila, but I hesitate to print my diagram, because a map conveys an impression of certainty and definiteness which in this case would be erroneous.†

"To the northward of Manila the same scheme of ranges seems less plausible. I am almost inclined to think that the Sierra Madre and the Caraballo del Norte, which are composed largely of crystalline schists, are each made up of short arcs belonging to each system. Some support for this guess is to be found in Mr. d'Almonte's large map of Luzón, where the watersheds show several zigzags. This region is perhaps a 'horst' in Mr. Suess's sense. As for the Sierra Zambales, it seems to me most probable that it continues southward through Pico de Loro and cape Santiago to the lofty Alcon peak, in Mindoro, and so into Mariveles through Pico de Loro to Balayán, near cape Santiago, in Batangas province. The western range of middle Luzón would

* l. c., pp. 545.

† Dana called attention to the symmetry exhibited in the trends of the islands. "Thus the body of Luzon is at right angles with the southern extremity; Palawan is at right angles nearly with Mindoro," etc. He also points out that both of the two systems of trends are curved.

thus be affiliated with the system with a northwesterly trend. Mr. von Drasche, however, calls attention to the fact that the Sierra Zambales exhibits a remarkable double repetition of the two main directions of Luzón, one northerly, the other northwesterly. With Arâyat I can do no better than leave it in its impressive loneliness."

The latest information regarding the outer groups of the Malayan archipelago is contained in Koto's paper, already cited. In his geomorphologic studies von. Richthofen has included a general and, except that Japan is not included, a summary paper especially devoted to the genesis of the island arcs.* He ascribes the dislocation planes represented in the arcs to the operation of tension, as has already been partially explained in an earlier review of this series. This theory advanced in the studies to the present writer appears less satisfactory than the descriptive portions which have been already reviewed, and on this account is left without further comment to the reader. The paper is of especial interest to an American reader for the reason that it presents the views of this great geographer and illustrates by examples the terms which have gradually come into use by the Austrian and German schools to describe the composition of mountain systems.

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A THEORY OF ORIGIN FOR THE MICHIGAN GYPSUM DEPOSITS.†

By G. P. Grimsley, Morgantown, W. Va.

The most generally accepted theory of origin of the large deposits of gypsum and salt, has been the evaporation of salt water lakes, bays, and seas, cut off from the main ocean. This theory has been given for the Iowa, New York, and Kansas deposits in the reports on salt and gypsum in those states. In the Kansas report, the writer endeavored to picture the history of the changes resulting in the deposition of gypsum in a bay whose waters retreated to the southwest in Permian time.

* Von Richthofen: Geomorphologische Studien aus Ostasien. IV. Uber Gebirgskettungen in Ostasien, mit Ausschluss von Japan. Sitzungsber. d. k. pr. Akad. d. Wiss., vol. 38, 1903, pp. 867-891.

† Published by permission of the Director, Michigan Geological Survey.

When such a body of salt water is cut off and [illegible] the gypsum is deposited after 37 per cent. of [illegible] and common salt only after the removal of 93 per [illegible] normal order of these formations would be a deposit [illegible] sum, and then a much heavier deposit of salt [illegible] per cent. of the water must be evaporated before [illegible] be thrown down, the evaporation might go far [illegible] deposition of gypsum, but not far enough [illegible] might be deposited and subsequently [illegible] first condition apparently [illegible] place in the Kansas [illegible] and both conditions probably [illegible] in Michigan.

In most areas, [illegible] than the [illegible] sufficient [illegible] has led to a number [illegible] Oklahoma and in Canada [illegible] the origin of gypsum [illegible] alteration of limestone [illegible] waters of springs [illegible] the reports [illegible] gypsum [illegible] Mediterranean [illegible] ing current [illegible] [illegible] ing would [illegible] evaporation [illegible] [illegible] 100 [illegible]

[illegible]

The [illegible] [illegible] rounded [illegible] Monroe [illegible]

In [illegible] stone [illegible] [illegible]

group, or the Upper Marshall, and the lower portion was called the Marshall group, equivalent to the Waverly in Ohio, and the Kinderhook of Illinois.

Above this series, in the vicinity of Grand Rapids, is a group of shales, limestone, and gypsum layers, called by Winchell the Michigan Salt group. This formation has been shown by Rominger and Lane to be destitute of salt beds, and the Saginaw valley and principal Michigan brines come from below this horizon, so that it seems advisable to follow Lane* and call it merely the Michigan group.

Above the Michigan group comes the Carboniferous limestone of Winchell, exposed at Grand Rapids and other places around the border of the Coal Measure basin. It is equivalent to the Bayport limestone of eastern Michigan, to the Maxville limestone of Perry and Muskingum counties in Ohio, and to the upper part of the St. Louis limestone of the Mississippi valley. Over the Carboniferous limestone, the Saginaw Coal Measures are found forming the interior basin. The Waverly group of Michigan, including the rocks described up to the Carboniferous limestone, according to Rominger,† "forms underneath the drift, the surface rocks over half the extent of the Peninsula, but its natural outcrops are very limited, either horizontally or vertically."

The Mississippian series in Michigan forms a basin-shaped fold, and in the center of the Peninsula it is overlain by the Coal Measures, and can only be mapped in such sections by the aid of well records.

The whole series of Michigan presents more or less irregularity, in places represented by shales, and again by sandstone apparently contemporaneous. The Michigan group in places is cut out entirely on the border of the Coal Measures, and again the Bayport limestone is present and the lower gypsum beds are gone. This limestone at Grand Rapids is about 50 feet thick and rests on the gypsum formation.

In the interpretation of the geological history revealed by these rocks and their relations, the writer wishes to acknowledge his indebtedness to the various papers of Weller, Lane, and Keyes.

* *Mich. Geol. Survey*, vol. vii, part II, p. 18.
† *Mich. Geol. Survey*, vol. iii, part I, p. 69.

GEOLOGICAL HISTORY OF THE MICHIGAN BASIN.

At the opening of the Carboniferous period, Lower Michigan, Ohio, and a large part of Pennsylvania, were covered by a gulf which opened to the northwest across Illinois and Minnesota. In the earlier part of the Mississippian epoch, the land was sinking around this gulf, especially to the south and southwest and in this sinking area were deposited the sediments of the Kinderhook stage, forming limestones, sandstones, and shales, mainly shallow water deposits irregular in extent, varying in fossil contents, so that the same series of rocks has been given a variety of names by geologists. These names are often used in local geology, but now are known to be contemporaneous, and they are included under the name of Kinderhook.

By the close of this divison of time, the large gulf extended south into Arkansas and Tennessee and west to the Rocky mountains, and opened northwest across the Dakotas.

For a long period of time the salt water gulf remained stable and quiet, supporting a rich fauna of corals and crinoids, which have formed the Burlington and Keokuk limestones, known throughout the world on account of the variety and perfection of their crinoid and brachiopod fossils. These limestones and other formations, related in time, have now been grouped under the name of Osage or Augusta.

While there were many local and minor variations in the physical conditions, and therefore in the life characters in this gulf, there was a greater and more important contrast in these characters between the eastern and western portions, separated by the Cincinnati island. These have been named by Weller* the eastern or Waverly province, and the western or Osage province.

In the Kinderhook gulf the faunas were intermingled to a very considerable extent; but in the Osage age the clear waters of the Osage gulf supported a fauna which could not flourish in the sediment-laden waters of the Waverly province.

The land to the northeast of this Carboniferous gulf was above sea level, the drainage system of that highland carried a large quantity of mud and sand sediment into the Waverly gulf, forming the conglomerates, sandstones, and shales of that area.

* *Journal of Geology*, vol. vi, p. 308.

The Cincinnati island afforded a partial barrier to the drifting of the sediment into the clearer Osage waters beyond.

At the close of the calm Osage age came a series of uplifts and depressions, whose effects are seen in the Mississippi valley and at the east. The St. Louis limestone was formed in waters extending 200 miles further north than those of the Osage, and this northward extension was followed by a retreat of 400 miles to the south.

In the eastern part of the Waverly gulf, the changes began earlier than in the Osage gulf, and the coast line, according to Lane,* receded westward from western New York and central Pennsylvania, until a large part of Ohio and Indiana were out of water by the end of the Marshall or Waverly age. This left the Michigan basin enclosed between the mass of land at the northeast, and probably also at the northwest, and the low land over northern Ohio and southern Michigan.†

On the south side of this low land were deposited the sediments forming the coarse sandstones and conglomerates of the Logan group laid down irregularly in Ohio with an average thickness of 200 feet. To the north side were deposited the sediments forming the rocks of the Michigan group, shales, limestones, and beds of gypsum.

The Mississippi extension of the St. Louis is represented in Michigan by the Bayport limestone, in Ohio by the Maxville, which come above the Michigan group. This group would correspond in time with the Burlington and Keokuk, or the Osage (Augusta) of the Mississippi valley. The thickness of the group in Michigan is 232 feet (Lane, Vol. VII, Part II, p. 16), the Augusta in Iowa is 230 feet, the Logan in Ohio is 200 feet.

MICHIGAN GROUP.

The Carboniferous, Bayport, or St. Louis, limestone in Michigan is also called by Lane the Upper Grand Rapids series, and the Michigan group is known as the Lower Grand Rapids.

At Grand Rapids, the typical locality for the section, the lower series outcrops to the south of the city as a group of shales, thin bedded limestones, and gypsum layers, while the

* *Michigan Geological Survey*, vol. vii, part II, p. 15.

† The extension of the Cincinnati island above mentioned.

upper series outcrops along the river in the city nearly to its north limits.* A number of quarries have been opened in the bed of the river, and, according to Rominger, the contact could be seen at the foot of the rapids in the earlier history of the city. This limestone is about 50 feet thick.

The only localities in Michigan where gypsum is found in this formation near the surface, are in the vicinity of Grand Rapids and at the east near Alabaster. The formation, however, is found in a belt of varying width bordering the coal basin, and through most of the area it is more or less concealed by the overlying drift.

QUANTITY OF GYPSUM IN THE ANCIENT MICHIGAN SEA COMPARED WITH THE PRESENT SUPPLY.

The area of rocks in Michigan after the Marshall or Kinderhook series is approximately circular in outline with a radius of 85 miles giving an area of 22,686 square miles. As will be shown later the sea covering this area in Osage times was approximately 700 feet in depth and assuming an average depth of 326 feet, based on well records, there would have been about 1,280,000 billion gallons of water.

The analysis of Atlantic ocean water shows 93.3 grains of gypsum to the gallon. If this Michigan sea had this same proportion, it would have yielded 8,500,000,000 tons of gypsum.

The thickness of gypsum at Grand Rapids is 18 feet and at Alabaster 20 feet. The approximate area at Grand Rapids is 24 square miles and at Alabaster 10 square miles, and while the gypsum does not by any means keep the thickness given over the entire area and is even absent in places, it has probably been removed by solution since its deposition.

These figures would give a total quantity of 1,237,764,000 tons of gypsum. Where gypsum is found in the deep wells it is usually in thin beds and in many of them it is entirely absent. It is thus evident that the quantity of gypsum held in this old Michigan salt sea is sufficient to explain the quantity of gypsum actually in existence today in its basin.

If the assumption is made, and there is no basis for it, that the gypsum covered all the interior sea area with a thickness of 20 feet, then it would require 917 billion tons of lime sulphate in

* See Whittemore *Proc. Mich. Acad. of Sciences.* Also Strong. *Proc Kent Sci. Inst.* No. 3.

the sea, more than a hundred times the quantity that probably existed in the basin.

CASPIAN SEA AS AN ILLUSTRATION OF THE MICHIGAN SEA.

The gypsum deposits in Michigan do not occur uniformly distributed through all parts of this old sea basin, but they appear concentrated in certain areas of comparatively small size. For the cause of this localization of the deposits we may look for a modern illustration to the conditions in the Caspian sea.

Into the northern part of the Caspian sea empty the Volga, Ural, and the Terek rivers bringing in a large quantity of fresh water so that in this portion of the sea the water is nearly pure with a specific gravity of 1,009. This small percentage of salt is, according to Van Baer, due to the number of shallow lagoons surrounding the basin, each being a sort of natural salt pan. At Novo Petrovsk a former bay of the main sea is now divided into a number of basins showing all degrees of saline concentration. One of these has deposited on its banks only a thin layer of salt, a second has a compact mass of salt on its floor, and a third has lost all the water and is a mass of salt covered with sand.

The concentration is seen on the greatest scale in the Karaboghay (Black gulf) of the Caspian, where the nearly circular shallow basin is about 90 miles across and almost entirely cut off from the sea by a long narrow spit of land, so that the gulf and sea are only connected by a channel not over 150 yards broad and five feet deep. Through this channel there passes into the gulf a current with an average velocity of three miles an hour, but which is accelerated by the western winds.

This current is due to the indraught produced by excessive evaporation from the surface of the basin due to the heat and winds. The shallow depth of the bar prevents a counter current of highly saline water into the Caspian. This current carries into the Black gulf, according to Van Baer, 350,000 tons of salt daily. If this dividing bar of land should be elevated and cut off the basin from the sea, the gulf would rapidly diminish and become a salt marsh, which later drying up would leave a large salt deposit.

With a greater depth of water over the dividing ridge the counter current would come in as at the straits of Gibraltar and the evaporation could go far enough for the deposition of gyp-

sum while the concentrated salt brine would pass back into the larger sea. This was more probably the condition in the Michigan gypsum basins as will now be shown from a study of geological conditions and well records.

MICHIGAN INTERIOR SALT SEA.

The Kinderhook sea of the American continent was an interior sea with a bay extending northeast into Michigan. In this bay were deposited the Marshall sandstones. The close of the period was marked by uplift in this area causing a retreat of the sea southwestward finally exposing a wide area of land in southern Michigan and northern Indiana. At Lafayette, Indiana, the floor of this sea was at least 563 feet above sea level. North of this barrier was a large interior sea with its floor 375 feet above sea level near Grand Rapids, lower by nearly 200 feet than the ocean to the southwest. This area was surrounded by the Marshall series, at this time dry land, 777 (Kalamazoo), 983 (Coldwater), and 1000 (Hillsdale) feet above sea level on the south; 700 (Huron county) feet on the east; and 755 (Grayling) feet at the north. A sea, like the Caspian, with a depth at first of probably 700 feet or more and an area of 22,686 square miles.

In this sea were elevations and depressions, a ridge at Lansing 500 feet above sea level and a depression east of Saginaw 380 feet below sea level separated from the main basin by a ridge 187 feet above the sea floor.

This sea probably had its tributary streams coming from the highland at the north and northeast flowing down across the recently emerged flats of the Waverly and Marshall land, bringing a supply of sediment and doubtless salt from the Salina beds at the north. The lake basins of Michigan and Huron were not in existence at this time but belong to a much later chapter in the geological history of our continent. The irregular clay seams and the clay dividing planes in the gypsum represent an influx of sediment, wind blown material, or tidal currents.

As the evaporation of these waters went on, the first deposit would be carbonate of lime thrown down when the specific gravity was raised to between 1.0506 and 1.1304; by further concentration the gravity would reach 1.22 and in this interval gypsum would be deposited. At this period 37 per cent. of the

water must have been evaporated. If the sea was 700 feet in depth, it would now be 440 feet still covering the Saginaw ridge but exposing the Lansing ridge. Further well records might give a clue to other basins separated by ridges of land. The sea would gradually become like the Caspian with smaller basins around it, in which all degrees of concentration would be found.

In the deep basin near Saginaw the dividing ridge would be exposed before salt was deposited. In such an evaporating basin the deposit of salts would occur around the borders of the basin first, and by the influx of water across the Saginaw ridge the water in the concentrating basin was probably renewed, resulting in the 20 to 25 feet of gypsum now found in that area.

The normal order of deposits should be lime carbonate, on which would be a deposit of gypsum covered by layers of salt. In the present developed areas the gypsum rests on a limestone floor, but with no traces of salt over it. The salt deposits are below the gypsum series in the underlying porous Marshall sandstone. Further, in the salt series of Saginaw, Grand Rapids, and other places, there are no traces of rock salt, but the salt wells secure the salt from natural brines.

If the Michigan interior sea evaporated completely there would have been, on the assumption its waters were like those of the present Atlantic, 17.9 times as much salt as gypsum, and the salt over the gypsum or in the lower part of the basins toward the interior where the waters deprived of their gypsum content had retreated.

If these conditions were true, the salt might later have been removed by solution in downward percolating waters which dissolved the more soluble sodium chloride. The gypsum now remaining does show marked effects of solution agents, the surface being rounded and furrowed by solution, and in places it is entirely removed. These effects would have been far greater in common salt. The salt-laden waters or brines would flow downward along the slope of the rocks and through them, finally remaining at rest in the porous sandstones of the Marshall where it is now found. Further, the salt seems to be found in greater amounts toward the interior of the basin than near the edges; more at Saginaw, Ann Arbor, Lansing, etc.,

than at Tawas and Grand Rapids, though it is found in all these places.

Another possible explanation of the final history of this sea is to be found in the great extension of the sea in the next epoch when the St. Louis limestone was formed. The sea in the St. Louis epoch extended its borders north and south and passed across the interior basin of Michigan to Grand Rapids on the west and to Huron county on the east. Possibly this renewal of the waters took place before the Michigan sea had disappeared by evaporation or before it had evaporated enough to deposit a large quantity of salt except in certain smaller basins separated by the dividing ridges.

From the evidence of sandstones and shales of the Michigan series found in the well borings of the interior it would seem that the ocean flowed over the southern barrier into the interior basin a number of times before the greater St. Louis inundation, and at these times deposited the sediments which are lacking in gypsum and salt contents. At these times the water would be diluted, its specific gravity lowered so that precipitation of the salts would not take place. These overflowing waters, local in their occurrence, cannot be correlated with other sections unless with those of the Logan series of Ohio, whose origin may be similar.

In the deeper Michigan borings, gypsum appears to be replaced by anhydrite; but where the depth of concentrated waters is 325 feet, giving a pressure of ten atmospheres, anhydrite is formed instead of gypsum.

This theory as outlined for the Michigan gypsum deposits is based on the study of a few well borings and a comparative study of the conditions in the Caspian sea of today and those of the Michigan area as far as they can be determined. There is a wide range of probability involved and while the theory is advanced as a theory resting on limited data, it may be taken as representing approximately the conditions of origin of these deposits.

REVIEW OF RECENT GEOLOGICAL LITERATURE.

A Treatise on Metamorphism. By CHARLES RICHARD VAN HISE. Washington, D. C.: Monograph XLVII. The United States Geological Survey. Pages 1286; illustrated with 13 plates. Price $1.50.

The following is a summary of the volume:

This treatise is an attempt to reduce the phenomena of metamorphism to order under the principles of physics and chemistry, or more simply, under the laws of energy. Metamorphism is broadly defined to include all alterations of all rocks by all processes. The metamorphism of the sedimentary rocks was the first subject studied by the author and metamorphism has been a chief line of investigation with him for more than twenty years. Finding that the alteration of rocks was nowhere systematically treated, he took up the task of preparing such a work. It was supposed that this work would occupy two or three years, but as a matter of fact it required seven years, and an eighth year has been needed to put the volume through the press.

The book consists of twelve chapters. Chapter I discusses the geological principles upon which a classification of metamorphism may be based. From this discussion it is concluded that the only practicable classification of metamorphism is geological. It is found that the alterations of the outer zone of the earth are radically different from those of the deep-seated zone. Moreover, it is shown that the alterations in the upper zone result in the production of simpler compounds from more complex ones, whilst those in the deep-seated zone result in the production of complex compounds from more simple ones. The upper zone is called that of katamorphism, and the lower zone that of anamorphism.

Chapter II, upon the forces of metamorphism, discusses chemical energy, gravity, heat, and light. The manner in which each of the classes of energy produces various mechanical and chemical effects upon rocks is set forth.

Chapter III treats of the agents of metamorphism. The agents of metamorphism are gaseous solutions, aqueous solutions, and organisms. Under aqueous solutions the chemical and physical principles controlling the action of ground water and the circulation of ground water are fully discussed. This involves a full resume of the science of physical chemistry so far as applicable to the alterations of rocks. This resume is not simply a summary from text books of physical chemistry, but discusses the applications of the principles to the phenomena of metamorphism.

Chapter IV, upon the zones and belts of metamorphism, discusses these zones and belts from the physical-chemical point of view. It is shown that the alterations of the zone of katamorphism occur with liberation of heat and expansion of volume, the chief reactions being

oxidation, carbonation, and hydration. The alterations of the zone of anamorphism occur with absorption of heat and diminution of volume, the chief reactions being deoxidation, silication with decarbonation, and dehydration. Thus the alterations in the two oppose each other. The zone of katamorphism is divided into two belts, that above the level of ground water, the belt of weathering, and that below the level of ground water, called the belt of cementation. While the physical-chemical principles of alteration are the same in each of these belts, the geological processes are very different. The belt of weathering is characterized by solution, decrease of volume, and softening, resulting in physical degeneration. The belt of cementation is characterized by deposition, increase of volume, and induration, resulting in physical coherence.

Chapter V treats of minerals. Each of the rock-making minerals is discussed with reference to its occurrence and alterations. The alterations are considered from the physical-chemical point of view. An attempt is made to write chemical equations which represent the transformations, and to calculate the volume relations resulting. It is found that a great number of rock-making minerals undergo two classes of changes, one of which is characteristic of the zone of katamorphism, and the other of which is characteristic of the zone of anamorphism. Perhaps the most important generalization of this chapter is as to the reversibility of reactions in the two opposing zones. This generalization is as follows: The equations which represent the reactions in the zone of katamorphism are reversible in the zone of anamorphism; and so far as there is expansion of volume and liberation of heat in the upper zone, just so far is there condensation of volume and absorption of heat in the lower zone.

Chapter VI considers the belt of weathering. The belt of weathering being the one which is most readily observed, has been treated by many authors. The chapter in this volume on weathering differs from previous discussions in that the phenomena are not considered mainly from the descriptive point of view, the emphasis being given to the classification of the phenomena and their explanation under physical and chemical principles. Also an important feature of this chapter is the consideration of the phenomena of the belt of weathering in relation to the alterations of the other belts of metamorphism.

Chapter VII treats of the belt of cementation. This belt is defined as extending from the belt of weathering to the bottom of the zone of fracture. The geological results are found to contrast very markedly from those of the belt of weathering. In the latter belt solution is the rule; openings are enlarged; the rocks degenerate. In the belt of cementation, upon the other hand, the processes of metamorphism continuously deposit material, the openings are closed, and thus the rocks are consolidated. Each of the cementing substances is considered, and an explanation is offered as to why cementation rather than solution is a general process in this belt.

Chapter VIII treats of the zone of anamorphism. This is the zone in which rock flow occurs. Full explanations of the meaning of rock

flow and of the development of such secondary structures as slatiness, schistosity, and the gneissosity are offered. Perhaps the most important generalization is, that "Rock flow is mainly accomplished through continuous solution and deposition, that is, by recrystallization of the rocks through the agency of the contained water. But rock flow is partly accomplished by direct mechanical strain. At the beginning of the process, during the process, and at the end of the process, the rocks, with the exception of an inappreciable amount, are crystallized solids."

Chapter IX treats of rocks. A classification of the sedimentary rocks is given, their genesis is discussed, and the series of transformations through which each of the rocks passes is traced out, the resultant rocks being indicated. It was not found possible to give a similar treatment for the igneous rocks.

With the ninth chapter the subject of metamorphism proper closes, but the results contained in these nine chapters have an important bearing upon other parts of physical geology. The remaining chapters consider these relations.

Chapter X discusses the relations of metamorphism to stratigraphy. It is shown that in consequence of metamorphism great difficulties are introduced in stratigraphical work. The nature of the difficulties and the manner in which they may be overcome are fully considered.

Chapter XI treats of the relations of metamorphism to the distribution of the chemical elements. This is perhaps the most daring of the various attempts at generalizing of the treatise. It is shown that as a result of the forces and agents of metamorphism the elements of the original igneous rocks are redistributed, a given element being less abundant in the larger number of sedimentary rocks than in the original rocks, and corresponding with this depletion each of the elements is segregated in one or more formations. An attempt is made to treat the problem of the redistribution of the elements quantitatively. Assumptions are made as to the total mass of the sediments and of the relative proportions of the more important classes of sediments. Combining these assumptions with the results of chemical analyses, the losses and gains of various formations for each of the important elements of the earth are considered. Many surprising results are reached. For instance, we find the conclusion that to oxidize the ferrous iron of the original rocks to the ferric condition in which most of it occurs in the sedimentary rocks, 35 per cent of the amount of oxygen in the atmosphere has been required. But still more startling is the conclusion that to oxidize the sulphur and iron of iron sulphides in order to produce the sulphates of the ocean and gypsum deposits, and to transform the iron to the ferric form required one and one-half times the amount now in the atmosphere.

The final chapter of the book, XII, is upon the relations of metamorphism to ore deposits. It is probable that this chapter will receive more general attention than any other. The material of the other chapters is of a kind which is likely to be of interest to the geologist only, whereas this chapter is of interest to all men concerned in the

great mining industry. The chapter upon ore deposits occupies 240 pages and, indeed, might have been named "The principles of ore deposition." From the author's point of view, the majority of ore deposits are produced by metamorphic processes. Having worked out the general principles of metamorphism with reference to rocks, the author found that the application of these principles to ore deposition explained the majority of ore deposits. From his point of view the proper theory of ore deposition consists mainly in bringing the particular phenomena exhibited by ore deposits under the general principles of metamorphism. The chapter contains a new classification of ore deposits, the fundamental divisions of which are the same as those of rocks. Thus ore deposits are divided into three classes, those of sedimentary origin, those of igneous origin, and those of metamorphic origin. Strictly the treatise on metamorphism should, perhaps, have considered only the third class. However, the first and second classes are sufficiently discussed so that the relations of these ores to those produced by metamorphic processes may be appreciated. The discussion upon ore deposits is too elaborate to be summarized in this general statement. But it may be remarked that for the metamorphic ores an attempt is made to trace out the solution, transportation, and precipitation of each of the chief economic metals. Also the alterations and further segregation of metals are fully considered. The conclusion is reached that in many cases an ore deposit does not represent a single segregation, but is the result of repeated segregations by the same general processes which result in the depletion in certain elements of the various rock formations and their segregation elsewhere. In other words the principles of the development of ore deposits are the principles of the segregation of those elements which are of importance to man, but which, for the most part, are so rare that they are not included in the discussion in the chapter upon the redistribution of chemical elements.

It is not possible in a summary to give any adequate idea of the scope of this treatise on metamorphism. A very broad range of facts, extending far beyond what might at first be regarded as a part of a treatise on metamorphism, is considered from the energy point of view. It is believed that the volume marks a great stride in the reduction of the entire subject of physical geology to order under the principles of physics and chemistry, and points out the way for a treatment of the entire subject from this point of view. H. C. R.

Volcanoes and Seismic Centers of the Philippine Archipelago. By REV. M. SADERRA MASO, Assistant Director of the Philippine Weather Bureau. Bulletin 3, Census of the Philippine Islands. Pages 80; with maps, outlines, and views from photographs. Washington, D. C., 1904.

This report, written for the Philippine Census by Father Maso, who, during the past fifteen years has been connected with the fully equipped seismic observatory in Manila, presents descriptions and history of the volcanoes and tracts of origin of earthquakes in this great

group or archipelago of islands, forming a part of the very long Pacific volcanic belt. The archipelago contains twenty well-known and recent volcanic cones, twelve of which are more or less active, ranging in hight from a few hundred feet up to about 10,300 feet.

Earthquakes are frequent in large parts of the island group, including the neighborhood of Manila, slight shocks occurring at intervals of every few days or weeks; while more severe shocks, doing injury to property and life, happen in some part of the archipelago almost every year. Seismographic records have shown that some of these earthquakes, even though not destructive at their origin or epicenter, send their waves or earth tremors entirely around or across the globe.

In Manila very violent and destructive earthquakes occurred in the years 1600, 1645, 1658, 1665, 1728, 1796, 1824, 1852, 1863, and 1880. The earthquake of June 3, 1863, destroyed the Manila cathedral, burying many persons in its ruins, and also threw down 25 public and 570 private buildings. The average annual number of days having earthquakes at that city is twelve, with a minimum, for the years 1880 to 1897, of five, and a maximum of twenty-six. W. U.

Mount Stuart Folio, Washington. By GEORGE OTIS SMITH. Geologic Atlas of the United States, Folio No. 106. Pages 10; with four maps, and six sections. Washington, D. C., 1904.

The quadrangle which is here mapped and described extends half a degree in latitude and longitude, lying on the eastern slope of the Cascade range. On the north, it includes Mount Stuart, rising 9,470 feet above the sea, fifteen miles east from the main Cascade range, of which an eastern spur, named by Russell the Wenatchee mountains, culminates in this rugged peak. Southward the quadrangle reaches to Ellensburg, in a broad flat expansion of the Yakima valley. Thus it comprises a great range of geologic formations, from the oldest to the youngest rocks known in the region of the northern Cascades.

The oldest formations, constituting the Mount Stuart massif and the lower peaks near it, are metamorphic sedimentary and eruptive rocks, probably of Paleozoic age.

In the south and east parts of the quadrangle are strata of Tertiary age, partly sediments, but most conspicuously represented by the Miocene basaltic eruptions, in which thousands of cubic miles of lava welled up from the earth's interior through numerous vents.

During late Pliocene and early Pleistocene time a great uplift of the belt forming the Cascade mountains took place, and subsequently streams and weathering have sculptured the mountains into their present outlines. Glaciers in the valleys about Mount Stuart, and, west of this quadrangle, on the headwaters of the Yakima river, largely aided in supplying extensive alluvial deposits of gravel and sand in the Teanaway and Yakima valleys, making the principal lands of agricultural value. W. U.

Review of the Glacial Geology of the Southern Peninsula of Michigan. By FRANK LEVERETT. Reprinted pages 100-110, from the Sixth Annual Report of the Michigan Academy of Science, 1904.

This is an excellent condensed summary of the author's elaborate observations and conclusions, from extensive field work, aided by Mr. F. B. Taylor and others, for the United States Geological Survey. In due time their detailed studies are expected to be fully published as a monograph similar to the two of Mr. Leverett's authorship already issued, which describe the glacial and lacustrine formations south of the great Laurentian lakes, from Illinois to New York.

The full monographic report on this peninsula, between lakes Huron and Michigan, will doubtless add much to our knowledge of the methods of erosion, transportation, and deposition of drift formations, as the following quotation from this advance summary indicates: "The structure of the drift is more variable in Michigan, both on the surface and below, than in a large part of the neighboring states of Ohio, Indiana, and Illinois. In those states the till or commingled drift greatly preponderates over sand and gravel, and contains a large percentage of fine clayey material. In Michigan sand and gravel form a notable part of the drift material, and much of the till is loose textured. This great amount of loose textured drift seems attributable to the excessive glacial drainage resulting from the convergence of the ice lobes. It is best developed in the high portions of the state which were built up between the ice lobes. In the plains next to the lake basins, where the ice was spreading out, the till or ground moraine is compact and clayey, as it is in states to the south where the ice lobes were free to spread."

A bibliography of about 50 titles, comprising publications that have added materially to the knowledge of the Pleistocene features and deposits of Michigan, is appended to this short paper; and it is stated that the geologic literature of the Great Lakes includes more than 200 titles. W. U.

Manual of Chemical Analysis of Rocks, by HENRY S. WASHINGTON, PH.D. New York. Wiley & Sons, 1904. pp. 183. $2.00.

The great advances that have been made of late years in silicate analyses and the high standards set by modern petrographers, particularly the advocates of new systems of classification, have, in many instances, served but to discourage the worker who is dependent wholly upon his own efforts for analyses as well as for microscopic research and field work.

The excellent work done by Hillebrand* was a great help, but it has remained for Dr. Washington to prepare a manual in which the whole field of silicate analysis, so far as is necessary in petrography, has been covered in such a manner that no one competent to make analyses at all has longer excuse for poor work.

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* Some Principles and Methods of Rock Analysis. *Bull. 176, U. S. Geological Survey.*

Dr. Washington is himself both a petrographer and a chemist. The methods given are either his own or those of the best workers in the field and have been tested by himself. They are, therefore, practical methods. A pleasing, but in this case not unexpected, feature of the work is Dr. Washington's evident disposition to give full credit to everyone upon whom he has drawn for information. The book should be in the hands of everyone who has occasion to make rock and mineral analyses. G. P. M.

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Ueber die gegenseitigen Beziehungen zwischen der Petrographie und angrentzenden Wissenschaften. (Jour. Geol., vol. 12, pp. 485-501, Sept.-Oct., 1904.)

PERSONAL AND SCIENTIFIC NEWS.

DR. J. C. MERRIAM, professor of Paleontology at the University of California, has returned from a summer's European trip.

THE UNIVERSITY OF THE PACIFIC, San José, California, has secured the instructional services of Mr. J. C. Hartzell in Geology.

MR. FRANK SPRINGER, Las Vegas, New Mexico, was elected June 8 a corresponding member of the Geological Society of London.

MR. D. H. NEWLAND, one of the associate editors of the Engineering and Mining Journal, has been appointed assistant state geologist of New York.

DR. W. C. MENDENHALL, of the U. S. Geological Survey, with headquarters in Los Angeles, has completed the investigations of most of the artesian basins of southern California.

MR. E. H. SELLARDS, A.M. (Kansas State University) and Ph.D. (Yale), has been appointed professor of entomology, geology and zoology in the University of Florida, at Lake City.

HENRY MCCALLEY, assistant state geologist of Alabama, died November 20, 1904, of pneumonia, aged fifty-three years. He had been connected with the Alabama survey since 1878.

ROBERT SIMPSON WOODWARD, dean of the School of Pure Science at Columbia University, has been elected president of the Carnegie Institution to succeed Daniel Coit Gillman, resigned.

DR. J. C. BRANNER, OF STANFORD UNIVERSITY, has returned from Europe and will be in Washington, D. C., until the meeting of the Geological Society of America at Philadelphia, in January.

SIR JOHN MURRAY, editor of the publication of the scientific results of the Challenger expedition, lectured before the Geographic Society of Chicago on Thursday evening, November 3d. His subject was "The Ocean."

DR. RALPH ARNOLD, of the U. S. Geological Survey, has returned to Washington, D. C., after completing some special investigations in the Tertiary formations of Washington, Oregon and California under the direction of Dr. Wm. H. Dall.

The Carnegie Museum of Pittsburg has purchased the library of the late J. B. Hatcher of that Museum and also that of the late professor C. E. Beecher of Yale. The first is especially rich in works on vertebrate paleontology, and the latter in works on invertebrate paleontology.

Dr. D. W. Johnson, of the Massachusetts Institute of Technology, has just completed a report on the "Relation of the Underground Waters to the Law." It will be published in the reports of the Eastern Section of the Division of Hydrology of the United States Geological Survey.

Dr. Geo. P. Merrill gave a paper, Nov. 23, before the Geological Society of Washington on "The Formation of the vein of so-called Asbestos (fibrous serpentine) at Thetford mines, Canada." At the same meeting Mr. Bailey Willis gave an illustrated lecture on "Some aspects of China."

Professor T. C. Chamberlin gave an address at the meeting of the Chicago chapter of the Society of the Sigma Xi on November 22d. His subject was "The theories of the origin of the earth." At the same meeting an exhibit from the department of paleontology of the University of Chicago was shown.

The Seventeenth Winter Meeting of the Geological Society of America will be held at Philadelphia, beginning December 29, at 10 o'clock a. m. Headquarters will be at the Walton Hotel, Locust and Broad streets. The meetings will be at College Hall, University of Pennsylvania. The president is J. C. Branner.

Dr. T. C. Chamberlin under the Auspices of the Sigma Xi Society on December 2nd gave a lecture in the auditorium of the Ohio State University on "Some hypotheses as to the origin of the earth." An audience composed of students, professors and residents of Columbus, numbering at least 1,000, listened for more than an hour to a most scholarly and interesting address.

The United States Geological Survey has just completed an arrangement with Dr. T. L. Watson, the recently appointed State Geologist of Virginia, for cooperation in the investigation of the artesian waters of that state. These investigations will be carried on during the winter and following summer by Mr. M. L. Fuller of the United States survey in conjunction with Dr. Watson of the State survey, and a joint report will be prepared early in the fall of 1905.

National Geographical Society. In the popular meetings planned by the Society for the year 1904-'05 is a lecture on April 21, by G. K. Gilbert, on "Niagara Falls." At the scientific meetings the following subjects of geological interest will be discussed: "Glacial erosion," by W. D. Johnson and G. K. Gilbert, November 18th: "Geography of Alaska," by A.

H. Brooks, December 2d; "A geologist in China," by Bailey Willis, December 16th; "Physiography of the American deserts," by G. K. Gilbert, January 27th.

"A TREATISE ON METAMORPHISM," by President C. R. Van Hise, has just been published by the United States Geological Survey as Monograph XLVII. The price is $1.50. This is the most complete treatise on metamorphism yet published, and comprises a volume of nearly 1300 pages. Besides accounts of the metamorphism of various rocks there are discussions on the origin and changes of each rock forming mineral, on the origin and redistribution of the chemical elements, and on the relation of metamorphism to ore deposits.

PROF. GEORGE J. BRUSH'S COLLECTION OF MINERALS AND LIBRARY have been presented by Prof. Brush to the Sheffield Scientific School of Yale University. The gift is accompanied by a fund of ten thousand dollars the income of which is to be used for the increase and care of the collection and library. The value of the entire donation is estimated at about forty thousand dollars. The collection has been made by Prof. Brush during the last fifty years, and is rich in type specimens of new minerals. It will be henceforth under the charge of Prof. S. L. Penfield.

GEOLOGICAL SOCIETY OF WASHINGTON. At the meeting of November 9th the following program was presented: S. F. Emmons, "Remarks on copper deposits near the Grand canyon, Arizona;" W. H. Weed, "Dilation fissures and their contained ores;" M. L. Fuller, "Evidence of caves at Put-in-Bay, Ohio, on question of land tilting"; C. W. Purrington, "A journey in the eastern Altai, Siberia."

THE UNIVERSITY OF CHICAGO has arranged for the following special courses in geology during the winter and early spring. I. Courses in non-metallic economic geology, by Dr. E. R. Buckley, State Geologist of Missouri; these courses include an elementary course and an advanced course on structurai materials; January 2d to February 10th. II. A course on Pre-Cambrian geology by Professor C. K. Leith of the University of Wisconsin; this course will be accompanied by laboratory work for those who so desire; February 13th to March 24th. III. Courses on ore deposits by Dr. F. L. Ransome, of the U. S. Geological Survey; these include an elementary course on ore deposits in general, and an advanced course on gold, silver, copper and lead (in part) ores; April 13th to May 12th.

THE THEODORE D. RAND COLLECTION of over 20,000 minerals and rock specimens has been presented by his daughter, Mrs. Charles Stillwell Eldredge, of Radnor, Pennsylvania, to the geological department of Bryn Mawr college. This

collection, which represents the enthusiastic and painstaking labor of Theodore D. Rand, Treasurer for 31 years of the American Institute of Mining Engineers, is remarkably complete. It contains many rare minerals, seldom found in private collections and many valuable and interesting crystals. The minerals have been secured by purchase and exchange from all parts of the world. The rock collection illustrates a more limited geographic district. It is thoroughly representative of the rocks of eastern Pennsylvania and includes a fine series of polished Serpentines, a rock type of which Mr. Rand had made a special study.

This collection is now being installed at Bryn Mawr college under the direction of Dr. F. Bascom, associate professor, and Dr. Benjamin L. Miller, associate in Geology.

Dr. Marsden Manson, of San Francisco, gave, by request, a lecture at Washington on the "Evolution of Climates," before the Washington Philosophical Society.

The Coal Fields of Cape Lisburne, Alaska. Near cape Lisburne, which is on the Arctic coast of Alaska, 300 miles north of the arctic circle, are two coal-bearing formations of economic importance. They were studied during the past summer by Mr. Arthur J. Collier, of the United States Geological Survey, who, assisted by Mr. Chester Washburn, made his way in an open dory along that distant shore as far east as cape Beaufort.

Of the two coal-bearing formations, one, which lies east of cape Lisburne, is of Jurassic or Lower Cretaceous age, and the other, which lies south of cape Lisburne, is either Lower Carboniferous or Devonian. The Mesozoic coal-bearing formation, which has been known for the last three-quarters of a century, commences at a point 25 miles east of cape Lisburne and is continuously exposed along the coast to cape Beaufort, a distance of 40 miles. It contains the well-known Corwin and Thetis mines, the location of which has been shown on many recent maps of Alaska.

Geologic study shows that the coal measures of these fields have a total thickness of at least 15,000 feet and contain not less than 40 beds of coal, each over a foot thick. The aggregate thickness of all the beds seen by Mr. Collier is over 150 feet. Eleven of them are more than four feet thick and contain coal of good quality. Analysis of samples from some of the beds shows the product to be low-grade bituminous coal. A limited amount of coal has been mined here since 1879 for whalers and revenue cutters. Several cargoes were mined in 1901 and sold at Nome markets for $18 and $20 a ton, in competition with Comax and Washington coal at $25 a ton.

None of the coal beds has been permanently developed. The coal produced was mined from the croppings along the

sea cliff and boated off to the ships through the surf. There is no harbor for vessels nor protection from any but south winds. In 1903 a small amount of coal, probably not exceeding 20 or 30 tons, was produced at the Corwin mine. In 1904 about 20 tons were taken by the steamship *Corwin* and about 10 more tons were mined for consumption at the Point Hope whaling station.

The Paleozoic coals outcrop at three points along the coast, 4, 8 and 12 miles, respectively, south of cape Lisburne. The coal-bearing formation extends southward for a distance of about 40 miles, and reaches the coast again at cape Thompson. Beds over four feet in thickness occur at each of the localities noted. No analysis of these coals has yet been made. They are bituminous and of considerably better grade than the Mesozoic coals of the region. They are totally undeveloped, but in 1903 a few tons were mined from croppings in the sea cliffs and used at the Point Hope whaling station.

THE AMERICAN INSTITUTE OF MINING ENGINEERS is planning for an excursion to British Columbia and Alaska as its summer meeting. The excursion party is expected to leave Chicago June 24th, by special train, running direct to Victoria. After the sessions at Victoria, an excursion of about 21 days will be made by chartered steamer and special train to Snettisham bay, the Treadwell mines on Douglas island, Juneau, Shakan, Skagway, White Horse, Lake Labarge, Dawson (at the mouth of the Klondike), the neighboring mining camps, and back to Victoria. On the way east from Victoria, five days will be spent in visiting mining districts in British Columbia (including, probably, Nelson, Rossland, Trail, Greenwood, etc.); and the party will reach Chicago about August 3d.

Errata for Volume XXXIV.

Page 122, line 11 from the bottom, for "numerals," read minerals.

Page 178, after line 17 from the bottom supply the omitted line: of the Sacramento range dip with a long slope to the Pecos.

Page 194, line 7, for "Obolla" read Obollela.

Page 244, first line, for "reconcentration" read recementation.

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